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PREFACE

Difficulties of maintaining longevity and productivity of stone fruit trees have been the motivation for four workshops on the subject. Workshops have now been held at Michigan State in 1982, Kearneysville, West Virginia in 1984, Clemson, South Carolina in 1986, and Kearney Agricultural Center, Parlier, California in 1988.

While in the San Joaquin Valley of California from September 25 through 28, 1988, the participants in this workshop visited field sites from Sacramento to Parlier, California. Field stops included Bacterial Canker Complex, nematode damage, virus disorders including Peach Stunt and Prunus Necrotic Ringspot Virus, Mycoplasma disorders such as Buckskin of Cherry, Phytophthora and Armillaria root rots, cover cropping systems and a packing shed. These tours included visits to all the major *Prunus* spp. as well as breeding material such as that located at the USDA Fresno breeding program.

Over a two day period, formal presentations on the subject matter contained herein were reported and discussed. Information exchanged across traditional scientific disciplines is the essence of this and previous Stone Fruit Decline Workshops. I wish to thank all the participants and the session leaders for their time and energies during this interdisciplinary exchange.

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CONTENTS

Virus Session

INFLUENCE OF PRUNUS NECROTIC RINGSPOT VIRUS ON GAS EXCHANGE ACTIVITIES OF 'REDHAVEN' PEACH TREES GROWING ON LOVELL AND SIBERIAN C ROOTSTOCKS

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ABSTRACT

Young leaves and growing tip samples from peach trees (Prunus persica (L.) Batsch) of Redhaven scion on Lovell and Siberian C rootstocks, were assayed using ELISA microtechnique in 1985 and 1986 for the presence of Prunus necrotic ringspot virus (PRSV). These trees were infected through budwood in the nursery or from the natural spread within the orchard. The purpose of this study was to identify PRSV-infected trees and assess the impact of virus on the gas exchange activities (GEA) and concentrations of leaf chlorophyll (CHL) of single intact leaves of Redhaven on two rootstocks. Neither rootstock nor PRSV affected CHL. However, both PRSV infection and rootstock type showed significant influence on the rates of transpiration, stomatal conductance and net photosynthesis. Trees infected with PRSV and growing on Siberian C rootstock had the lowest GEA rates and leaf CHL while those free of PRSV and grafted to Lovell rootstock had the highest GEA rates and CHL contents.

Peach trees are susceptible to Prunus necrotic ringspot virus (PRSV) which is commonly found in most of the stonefruit-growing areas of the world. This virus exists in the form of several strains and is responsible for a diversity of foliar and bark symptoms on host plants (5,6). In the southeastern United States of America, symptoms of PRSV on peach trees include foliar chlorotic rings, necrotic spots or deformation, and bark necrosis and splitting, stem pitting and/or girdling (7). This virus is generally transmitted through seed and/or pollen and thus, is distributed in the propagating material (3,7). In peach, PRSV inhibits tree growth and reduces fruit yield (8). Moreover, this virus also causes withering of twigs and branches and sometimes, death of whole trees (9). Cochran (2) reported that, in general, various cultivars of peach show a similar range of symptoms; however, PRSV infection appears to be responsible for more damage to freestone cultivars of peach than to the trees of clingstone type of peach cultivars. Recently, Wells and Kirkpatrick (10) have associated PRSV with a slow decline of peach trees in middle Georgia. Yadava (12) and Yadava and McCrary (13) reported that gas exchange activities (GEA) of peach trees in declining health, which resulted from peach tree short life (PTSL) stress(es), were significantly influenced by rootstock type, planting site (with regard to its history of peach growing), and phytohormone treatments. However, there is a lack of specific information on the influence of PRSV on GEA of peach trees, particularly in relation to the PTSL syndrome. The present investigation was conducted to determine the influence of rootstock and PRSV infection on single leaf GEA rates and concentrations of leaf chlorophyll (CHL) in declining peach trees.

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MATERIALS AND METHODS

A peach (Prunus persica (L.) Batsch) planting, consisting of 192 trees of Redhaven cultivar growing on Lovell and Siberian C rootstocks, which was established in 1980 in randomized blocks with four replications, was used for this study. Trees were infected with PRSV from natural spread through pollen sources in the orchard or thorugh budwood in the nursery or both. Samples of growing shoot tips along with young leaves from all surviving experimental trees, were collected from each of four quadrangles of trees during late spring and early summer in 1985 and 1986. These samples were refrigerated at 5°C until needed, normally within 48 h. To determine the presence of PRSV in peach leaf and growing shoot tip samples, the enzyme-linked immunosorbent assay (ELISA) microprocedure of Clark and Adams (1) was used. The antisera were obtained from the American Type Culture Collection, Rockville, Maryland. Virus antiserum was prepared against isolate "G" of PRSV obtained from R.W. Fulton, University of Wisconsin. Composite samples of leaves and shoot tips from individual trees were ground in 0.1 molar sodium-phosphate buffer (pH 7.0) using a 1:20 ratio of tissue to buffer (w/v). Immunoglobulin and conjugated immunoglobulin were used at 1.0 ug ml^{-1} and were incubated for 4 h at 37°C for coating and conjugate fixing and for 12 h at 6°C for fixing test samples on to the ELISA plates. Each sample was tested in adjacent duplicate wells. Absorbance of the samples on ELISA plates was read at 410 nm wavelength using MR-600 Autoreader (Dynatech Instruments, Inc., Torrence, CA). The samples were judged positive for the presence of PRSV when their absorbance was 5 times greater than the absorbance of control wells, which contained PRSV-free peach samples from the same species and growth stages.

Gas exchange activities (rates of transpiration, stomatal conductance, and net photosynthesis) of 2 trees per plot, were monitored each month from May to November during 1985 and 1986, using the LI-6000 portable photosynthesis system (Li-Cor Inc., Lincoln, NB). The area concentrations of CHL were determined from SPAD-501 (a chlorophyll meter from Minolta Corporation) readings of same leaves taken simultaneously with GEA data, using a procedure recently developed by Yadava (11). Data for both years were pooled and analyzed by SAS using ANOVA procedures. The means were separated by Least Significant Difference procedure.

RESULTS AND DISCUSSION

General Observations

Neither GEA nor CHL observations were consistent for the entire season in either of two years. These inconsistencies appeared to be the result of several factors including variable and abnormal weather conditions, lack of precipitation, fruiting season, and other such environmental conditions that lead tissues to onset of dormancy. In general, the rate of photosynthesis seasonally declined from 21.16 umol CO_2 m^{-2} s^{-1} in May to 8.06 umol CO_2 m^{-2} s^{-1} in November. Similarly, the rate of transpiration varied from a low value of 5.04 umol H_2O m^{-2} s^{-1} in May to a high rate of 14.36 umol H_2O m^{-2} s^{-1} in August; rate of stomatal conductance ranged from a low value of 199.19 mmol m^{-2} s^{-1} in June to a high value of 455.74 mmol m^{-2} s^{-1} in August; and concentrations of leaf CHL declined from a maximum of 388.41 umol m^{-2} in August to the minimum of 326.13 umol m^{-2} in November.

Rootstock Effect

Rootstock type significantly affected GEA including the rates of stomatal conductance, transpiration, and photosynthesis, but showed no effect on CHL concentration (Table 1). Peach trees growing on Lovell rootstock had higher rate of stomatal conductance and transpired more rapidly than those trees budded to Siberian C rootstock. Similarly, Lovell rootstock enhanced the photosynthetic efficiency of trees by 7.8% over those trees on Siberian C. It is revealed from figure 1A that from May to July, tress on Lovell rootstock compared to those on Siberian C contained less CHL, but following this period, they had significantly higher CHL concentration. On the other hand, the rates of GEA for stomatal conductance, transpiration, and net photosynthesis, were consistently higher for trees on Lovell during most parts of both growing seasons (Figures 1B, 1C, 1D). Yadava (12) reported that Redhaven peach trees when grown on more vigorous rootstocks in three separate plantings, had higher GEA rates and CHL than on less vigorous rootstocks. Most often, Siberian C is a less vigorous rootstock than Lovell (Yadava, unpublished data). Additionally, peach trees on Siberian C rootstock are more susceptible to cold and bacterial canker (Pseudomonas syringae van Hall), which are the two major factors in PTSL.

These causal factors may be associated with the reduced efficiency of GEA rates and lower concentrations of leaf CHL. It has also been reported by Yadava and McCrary (13) that rootstock type imparts a stronger influence on the rate of photosynthesis than on other GEA parameters. Results from the present study are at least in partial agreement with the report of Yadava and McCrary (13).

Influence of PRSV

Similar to rootstock response, PRSV had no significant effect on leaf CHL, although the virus caused a slight reduction in CHL contents in the leaves of trees growing on Siberian C rootstock (Table 2). It is also seen in this table that infection of trees with PRSV significantly reduced GEA rates for stomatal conductance, transpiration, and net photosynthesis. Peach trees free of PRSV infection generally had higher concentrations of CHL than did infected trees during both seasons except in September and November (Figure 2A). Significant differences in stomatal conductance and transpiration rates due to the presence of PRSV were observed only during October (Figures 2B, 2C). Trees infected with PRSV appeared to be less efficient in GEA performance. During June, July, and August, the rate of net photosynthesis for virus-free trees was significantly higher than for PRSV-infected trees (Figure 2D). However, higher rates of net photosynthetic activity in PRSV-infected trees during the months of May and November (Figure 2D, may have resulted from variations in the stages of PRSV infection that were pointed out by Pine (8). According to Pine (8), certain strains of PRSV cause a slight growth suppression during the acute stage of virus infection and a very gradual decline (in growth) during the chronic stages of PRSV infection. Topchiiska (9) clearly stated that most peach trees may lack visual symptoms on foliage, but the PRSV infection by itself is capable of causing withering of branches and twigs leading eventually to death of whole trees. Mathews (4) emphasized that the most general result of virus infection is to cause a reduction in the photosynthesis and transpiration rates. Thus, variations in tree growth due to the stage of PRSV infection (8), may be a resultant of PRSV-caused variations in GEA and CHL. The reduction in GEA rates and CHL concentrations due to PRSV may be related to certain changes in the leaf morphology that have been suggested by Topchiiska (9). Moreover, the concentration of CHL (12,13), which were also markedly influenced by PRSV infection, appears very interesting. Nevertheless, for the lack of adequate information, it is difficult at this time to speculate whether or not there is an association between PRSV infection of trees and the development of short life in peach orchards.

From the observations made during the period of this study, it is concluded that PRSV as well as rootstock significantly influenced GEA rates and CHL levels of single intact leaves of Redhaven peach. Furthermore, the PRSV effect seemed to be greater than the rootstock influence.

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Table 1.
Influence of rootstock type on chlorophyll content and gas exchange activities of single intact leaves of Redhaven peach during the growing seasons of 1985 and 1986.[z]

	Rootstocks	
Variables	Lovell[y] (35-37)	Siberian C[x] (33-34)
Leaf chlorophyll ($umol\ m^{-2}$)	362.78[a]	361.83[a]
Stomatal conductance ($mmol\ m^{-2}\ s^{-1}$)	303.42[a]	265.21[b]
Transpiration ($umol\ H_2O\ m^{-2}\ s^{-1}$)	9.82[a]	9.21[b]
Photosynthesis ($umol\ CO_2\ m^{-2}\ s^{-1}$)	12.11[a]	11.23[b]

[x]Values represent a mean of 460 observations from 33-34 trees on Siberian C.

[y]Values represent a mean of 505 observations from 35-37 trees on Lovell.

[z]Means in rows followed by the same letters are not significant, LSD (0.05 p).

Table 2.
Influence of Prunus necrotic ringspot virus on chlorophyll content and gas exchange activities of single intact leaves of Redhaven peach scions on Lovell and Siberian C rootstocks during 1985 and 1986.[z]

	VIRUS STATUS OF PEACH TREES	
Variables	PRSV Negative[y] (20 - 22)	PRSV positive[x] (46 - 49)
Leaf chlorphyll ($umol\ m^{-2}$)	364.92[a]	361.10[a]
Stomatal conductance ($mmol\ m^{-2}\ s^{-1}$)	301.08[a]	277.28[b]
Transpiration ($umol\ H_2O\ m^{-2}\ s^{-1}$)	10.03[a]	9.29[b]
Photosynthesis ($umol\ CO_2\ m^{-2}\ s^{-1}$)	12.44[a]	11.32[b]

[x]Values represent means of 670 observations from 46-49 PRSV-infected trees.

[y]Values represent means of 295 observations from 20-22 non-infected trees.

[z]Means in rows followed by the same letters are not significant, LSD (0.05 p).

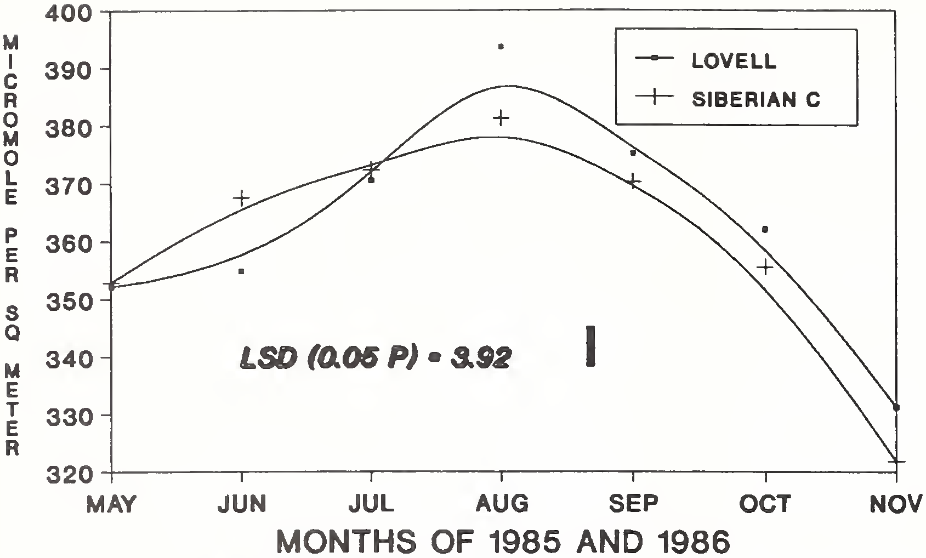

FIGURE 1A: Rootstock influence on area concentration of total chlorophyll in single intact leaves of *Redhaven* peach

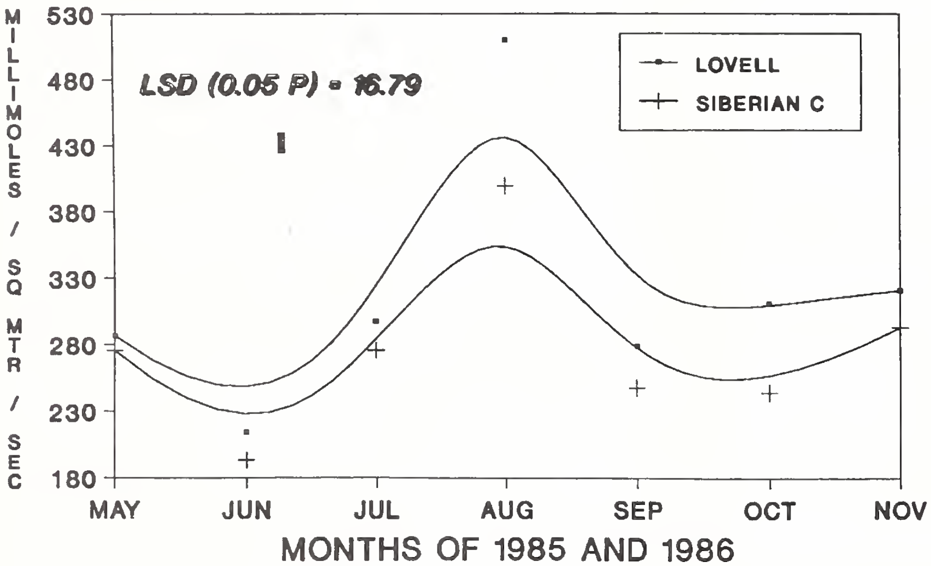

FIGURE 1B: Rootstock effect on rate of stomatal conductance of single intact leaves of *Redhaven* peach.

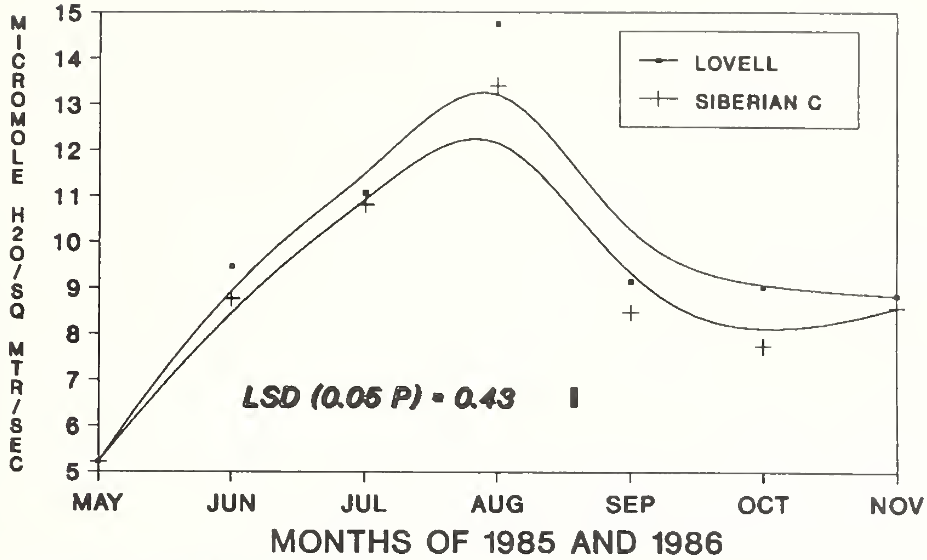

FIGURE 1C: Rootstock influence on rate of transpiration from single intact leaves of *Redhaven* peach.

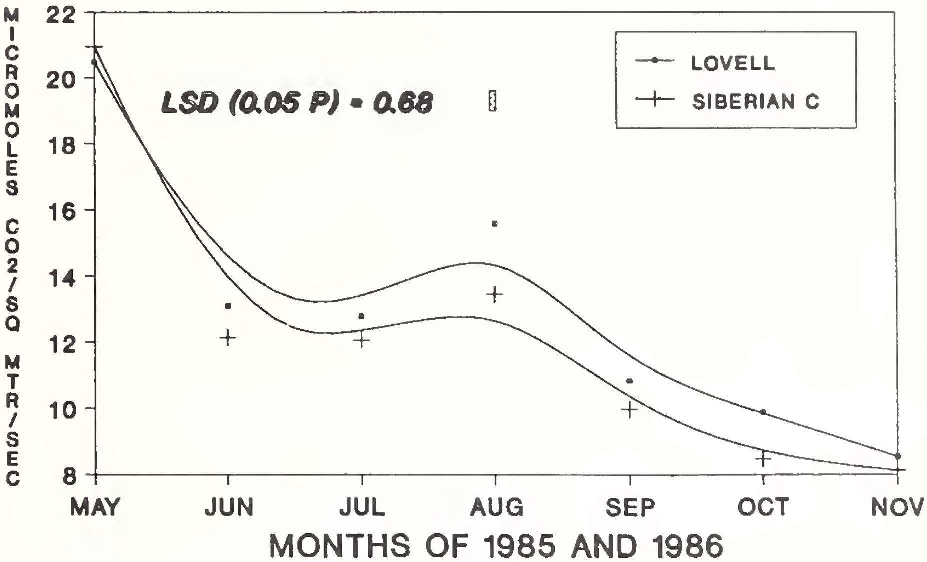

FIGURE 1D: Rootstock influence on the rate of net photosynthesis of single intact leaves of *Redhaven* peach.

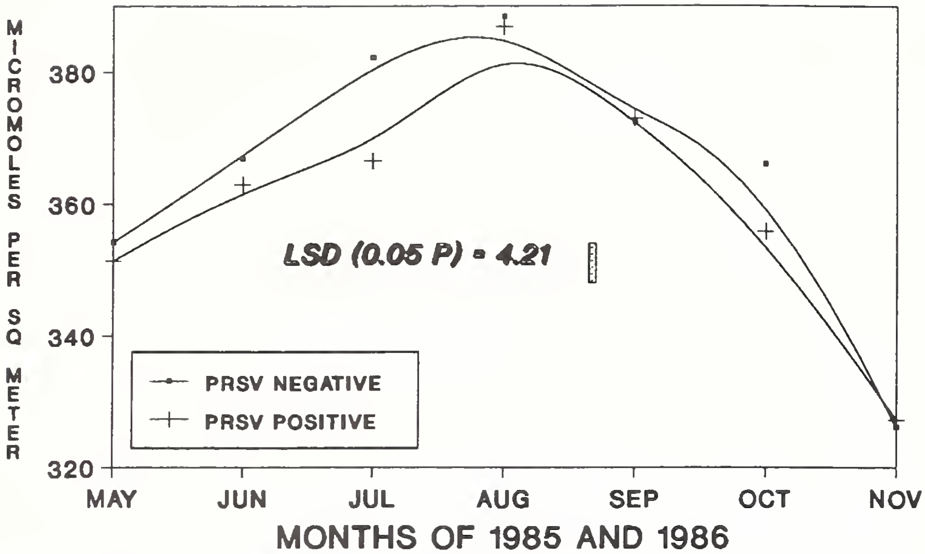

FIGURE 2A: **Influence of *Prunus* necrotic ringspot on chlorophyll concentration of single intact leaves of *Redhaven* peach.**

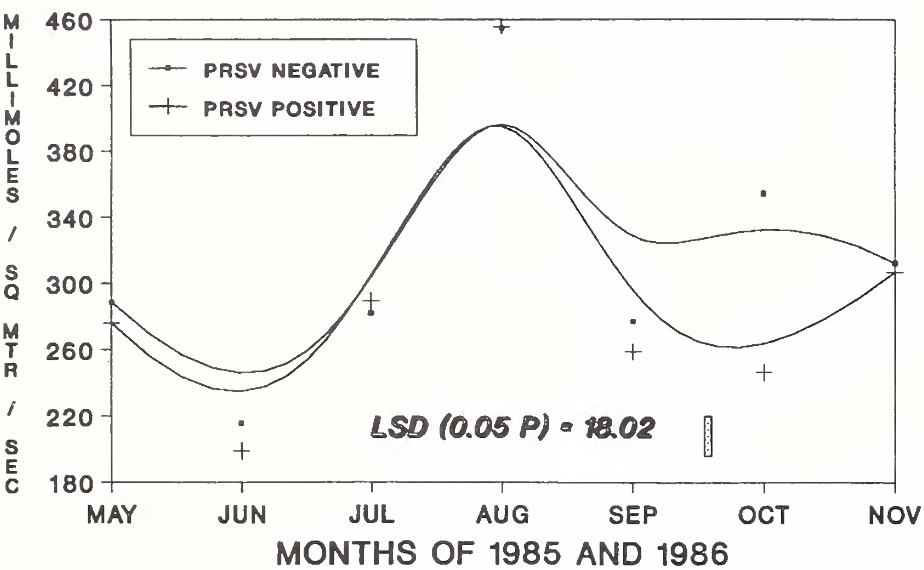

FIGURE 2B: **Influence of *Prunus* necrotic ringspot on the stomatal conductance of single intact leaves of *Redhaven* peach.**

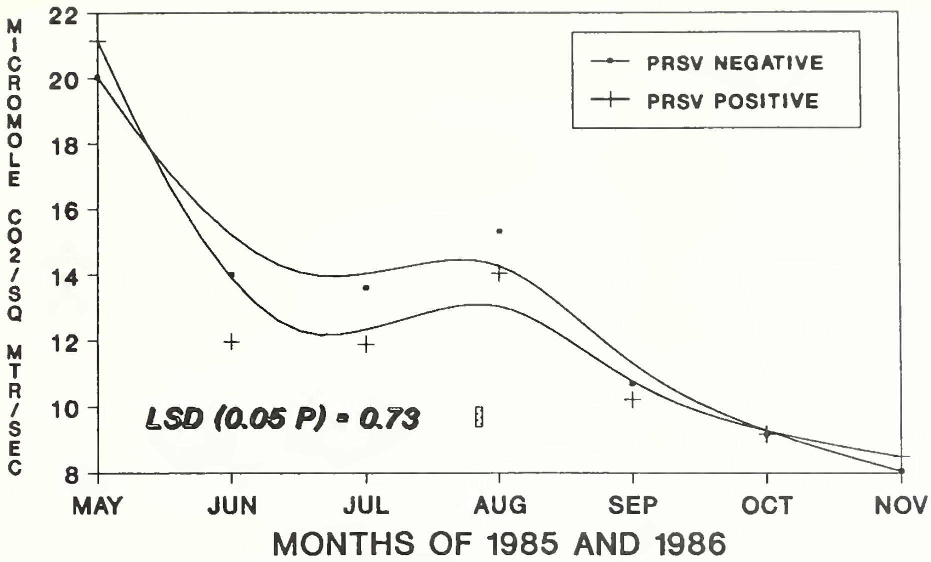

FIGURE 2D: Influence of *Prunus* necrotic ringspot on the net photosynthesis rate of *Redhaven* peach single intact leaves.

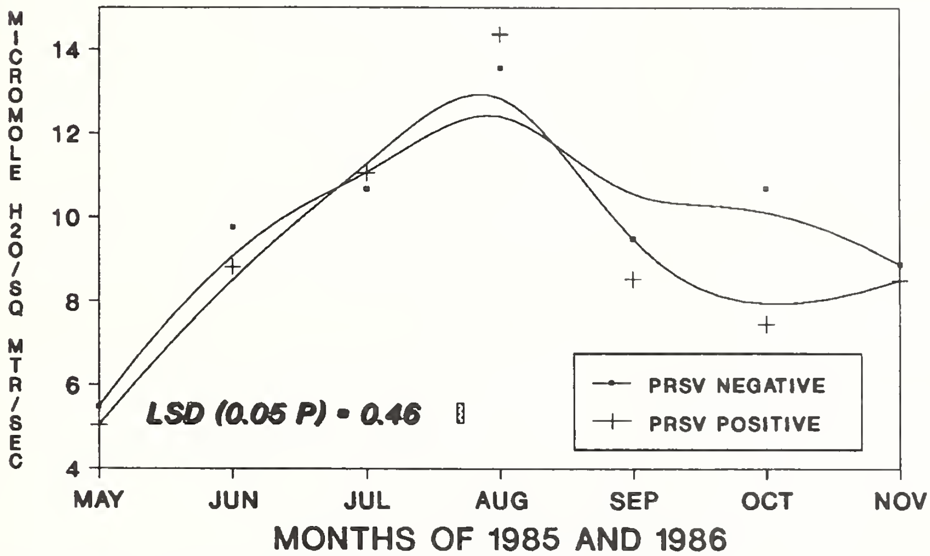

FIGURE 2C: Influence of *Prunus* necrotic ringspot on the transpiration rate from single intact leaves of *Redhaven* peach.

THE EFFECT OF PRUNE DWARF AND PRUNUS NECROTIC RINGSPOT VIRUSES ON YIELD OF YOUNG CLING PEACHES - A PROGRESS REPORT

Wesley K. Asai and Jerry K. Uyemoto

ABSTRACT

Two viruses, the prune dwarf virus (PDV) and Prunus necrotic ringspot virus (PNRSV) have been shown to have detrimental effects on cling peach yields. Losses of 0.9 to 2.5 tons per acre were reported for PNRSV diseased trees (1). The same report showed a 1.64 to 3.85 tons per acre decrease due to peach stunt disease (PSD). PSD is caused by PDV alone in highly susceptible varieties or by a combination of PDV and PNRSV in other varieties.

Both viruses can be seed-borne and pollen transmitted. This study examines the rate at which PSD spreads in both a second leaf infected orchard and a second leaf healthy orchard, which are adjacent to each other. This study also examines the effect of PSD on yield of these orchards and another third leaf orchard.

MATERIALS AND METHODS

'Carson'/Nemaguard peach trees (Prunus persica) were used in this study due to their known sensitivity to PSD. The second leaf orchards were planted at a spacing of 18 feet x 18 feet (134 tpa) and the third leaf orchard at a spacing of 8 feet x 14 feet (360 tpa). Both are irrigated by basin flooding.

The capacity to diagnose PDV and PNRSV was through a serological test called enzyme-linked immunosorbent assay (ELISA). The reliability of the ELISA test was ascertained by indexing onto Shiro-fugen flowering cherry (P. serrulata).

In the 2-year old orchard, 17 of 64 trees (in an 8 tree x 8 row arrangement) were diagnosed as PSD. The adjacent, 2-year old Carson orchard (separated by a pipeline used to irrigate both orchards) contained all healthy trees. These two test blocks were harvested together and two-pick harvested on July 14 and 21, 1988.

The 3-year old orchard involved a comparison of 20 stunted trees (these were diagnosed as PSD) with 20 trees with apparently normal growth and fruit set. This orchard was one-pick harvested on July 18, 1988.

RESULTS AND DISCUSSION

Testing for PSD in the 2-year old orchard began in the first year of planting and will continue for at least the next five years. Figure 1 shows the current distribution of PSD in the two 2-year old orchards.

Yields in the 2-year old orchard ranged from 0.7 tons/acre in the PSD trees to 1.6 tons/acre in the healthy trees in the PSD infected block to 1.3 tons/acre in the healthy adjacent orchard.

In the 3-year old orchard, trees with PSD averaged 5.5 tons/acre compared to the non-stunted trees which averaged 14.9 tons/acre. It should be noted that even though the non-stunted trees appeared normal, they did index positive with the Shiro-fugen index. This index, however, cannot differentiate between PDV and/or PNRSV so this needs to be confirmed by ELISA next season.

Figure 1

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. . . s s . . .   P   . . . . . . . .
. . . . s . s s   i   . . . . . . . .
. s s . . . . s   p   . . . . . . . .
s s s . . . . .   e   . . . . . . . .
. . . . . . . .   l   . . . . . . . .
. . . . . . . .   i   . . . . . . . .
. . s . . . . .   n   . . . . . . . .
. s s . . . . s   e   . . . . . . . .
s s . . . . . .       . . . . . . . .

Stunt Infected Side      Healthy Side
```

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UNION BROWNLINE AND STEM GROOVING: TWO DISORDERS CONTRIBUTING TO DECLINE OF ALMOND TREES

J.H. Connell, J.K. Hasey and Jerry K. Uyemoto

ABSTRACT

A union brownline (hereafter referred to as almond brownline, ABL) and almond stem grooving (ASG) are disorders that have been observed to affect almond trees (Prunus dulcis) on the plum rootstock, Marianna 2624 (P. cerasifera x P. munsoniana). Symptoms of ABL were observed on young trees of the almond cvs Carmel, Peerless, and Prince. With ASG, older Carmel trees were involved.

Our study was initiated to determine etiology of the two diseases and their incidence in commercial orchards.

MATERIALS AND METHODS

Almond brownline (ABL)

The symptoms of diseased trees varied in severity, with mildly affected trees showing one or more limbs with little or no current season shoot growth. Leaves on such limbs were tightly clustered (resulting in a rosette appearance) and darker green than normal. The internal bark tissues along the union contained scattered pockets of necrosis and corresponding mild pits in the xylem (woody cylinder). In advanced cases, the entire canopy consisted of poor shoot growth and small, drooped, and yellowed leaves. Affected trees died. The graft union exhibited an overgrowth and bark splitting along the union. Internally, a solid brownline (in the bark) and severe pits (xylem) were evident.

Trees with ABL were diagnosed in the counties of Butte, Colusa, San Joaquin, Sutter, and Yolo. Surveys were done in three young orchards to determine disease incidence. Also, extensive sampling of tissues and soils was performed in one severely diseased site. Here, scion shoots and root suckers with succulent leaves were collected from several symptomatic trees and used for graft inoculations onto a nursery source of Peerless almond on Marianna 2624 trees or double-budded with healthy Peerless buds (obtained from the Foundation Seed and Plant Materials Service, UC Davis; FPMS) onto rooted Marianna 2624 cuttings (from FPMS).

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Succulent tissues were extracted in nicotine based buffer and the juice rubbed onto carborundum dusted leaves of cucumber (Cucumis sativus) and Chenopodium quinoa or extracted (in lots of 100 g tissue) and analyzed for dsRNA content. Tissues were also tested by ELISA for ilaviruses and tomato ringspot virus (TmRSV).

A portion of the soil samples was screened for potential nematode vectors by the Cooperative Extension Service, Department of Nematology, University of California, Davis. In addition, soil baiting experiments were attempted. Lots of soil were divided and treated as follows: fresh (untreated), 30-day air dried, and autoclaved. Each soil treatment (placed in 2 to 7 15-cm plastic pots) received transplants of cucumber and C. quinoa seedlings and rooted Marianna 2624 cuttings. The herbaceous plants, after a 30-day exposure, were uprooted, washed, and roots extracted in phosphate buffer, pH 7.0, and the juice rubbed onto fresh seedlings of cucumber and C. quinoa. The potted Marianna cuttings were T-budded with healthy Peerless buds, which were forced to grow. All potted plants and trees were maintained in a water-cooled greenhouse.

Graft transmissions (by T-budding) were also attempted on P. tomentosa, an indicator for TmRSV. Candidate buds (from diseased shoots and suckers) were placed directly beneath an emerging P. tomentosa shoot. The indicator shoot was observed for symptoms and later (ca. 4-5 mo) the leaves were triturated in nicotine based buffer and rubbed onto C. quinoa.

Almond stem grooving (ASG)

Affected trees exhibited sparse canopies, early leaf drop, and a general decline. The woody cylinder contained numerous pits and grooves above and below the graft union. Orchards containing trees (principally the Carmel cv) with ASG were located on two sites in Butte County. The alternate rows planted to Price at orchard M appeared unaffected, while alternate rows of Monterey at the second orchard developed yellowed and drooped leaf symptoms, but later such trees showed recovery. Orchard M was surveyed for disease incidence and at both sites the soils, blossoms, leaves, and buds were sampled and processed as above.

RESULTS AND DISCUSSION

The incidence of ABL in the three orchards was 18% (68 symptomatic trees/379 trees), 15 (168/1120), and 3 (1/30). With ASG, orchard M had 11% diseased (19/173) and 31% replanted (53/173) Carmel trees. In the alternate rows, an equal number of Price trees appeared healthy (0/173).

The nematode content in 12 soil samples collected from ABL tree sites ranged from a low of 5 to a high of 750 Xiphinema americanum/liter soil. No Trichodorus sp. was recovered. Other plant parasitic nematodes detected were stunt (Merlinius spp.; zero to 1250/liter soil), root lesion

(*Pratylenchus* spp.; zero to 200), and ring (*Criconemella* spp.; zero to 30). Numbers of *X. americanum* in soil samples from ASG orchards varied from zero to 990/liter soil.

All bioassays of herbaceous bait plant and almond tissue extracts, ELISA tests, and dsRNA analyses were negative or inconclusive. With ABL, graft inoculations to *P. tomentosa* and subsequent indicator tissue assays also failed to demonstrate the presence of a biotic agent.

Results of our graft inoculations (done during 1987) are for the most part incomplete. Apparently more incubation time may be required before final readings can be taken. However, the transmissibility of the ABL factor, but not ASG, may have been realized. In the soil baiting experiments, 89 Marianna cuttings were transplanted into diseased soils, which were treated in various ways. Later the Marianna stock was T-budded with Peerless almond buds. During preliminary readings in early June 1988, 11 or 55 Peerless shoots exhibited bronzed leaves (Table 1). Examination of the unions of two symptomatic shoots revealed a light brown line in the bark tissues and fine pits in the xylem. The unions of two green-leafed shoots were normal. Symptomatic shoots were obtained with budling trees planted in all soil treatments (see Table 1), which suggests that one component of the tree was already infected and that the pathogen was unevenly distributed in the original source tree. In all probability (since 40 to 45-cm length dormant budsticks were used to produce the Marianna rootstock), the diseased source was the Peerless tree. Efforts are being continued to verify these findings and assumptions.

ACKNOWLEDGEMENTS

We gratefully extend an appreciation to Dr. Becky Westerdahl and Ms. Cindy Anderson for the nematode analysis and to the Almond Board of California for financial support.

Table 1.
Almond brownline: summary of soil baiting experiments using Marianna 2624 rooted cuttings and budded with cv Peerless almond

	Peerless buds that produced shoots with leaves:		Peerless buds that remain:	
Orchards (treatments)	green or	bronzed	dormant or	died
R (fresh soil)	4	6	3	2
(30-day dried)	12	1	0	11
(autoclaved)	3	3	0	0
Others: 6 orchards				
(fresh soil)	18	1	1	10[1]
2 orchards				
(autoclaved)	6	0	1	7
	43	11	5	30

[1]One shoot grew 60 cm and died.

VECTOR TRANSMISSION OF X-DISEASE MYCOPLASMA-LIKE ORGANISMS FROM CALIFORNIA

Alexander H. Purcell, Karen Gonot Suslow and Bruce C. Kirkpatrick

ABSTRACT

Isolates of X-disease mycoplasma-like organisms from different regions in California that were transmitted from naturally infected (i) cherry, (ii) prune, or (iii) from X-diseased peach (inoculated in the laboratory by field-collected pear psylla) were transmitted by the leafhoppers Colladonus montanus and Fieberiella florii from celery to celery. Two of the isolates were transmitted at rates below 5% per insect per week. The combination of symptoms, incubation period, and leafhopper transmission were distinctive for each isolate.

INTRODUCTION

X-disease is a decline condition of stone fruits presumably caused by a mycoplasma-like organism (MLO) (3,4). Distinctive differences in symptoms of X-diseased trees have been noted largely on a regional basis (2,5). Within California, for example, "strains" of X-disease have been described (Table 1) on the basis of disease symptoms in peach (Prunus persica L.) and cherry (P. avium L.). Differences in vector transmission between different X-MLO sources have also been noted (1).

The development of DNA-DNA hybridization probes for X-MLOs (3) have allowed direct comparisons of the genetic relatedness of different isolates. We have also evaluated differences in transmission of X-MLOs by leafhopper to celery (Apium graveolens L.), which is a sensitive host plant (2,9).

MATERIALS AND METHODS

Stock colonies of the leafhopper Colladonus montanus Van Duzee were reared on celery as previously described (1,8). Fieberiella florii Stal was reared in a similar manner on privet (Ligustrum ovalifolium). Periodically, colonies were tested for the absence of infectivity with the X-disease agent by exposing celery to the leafhoppers and then holding the plants in the greenhouse for over 2 months to monitor for X-disease symptoms. 'Tall Utah 52-70' celery seedlings were used for test plants, usually when less than 6 cm tall in 6 cm pots for individual leafhoppers and 8-12 week old plants in 15 cm clay pots for groups of leafhoppers. Peach test plants were 'Lovell' seedlings grown in either 10 cm plastic or 15 cm clay pots.

Immature insects (2nd to 5th instars) from stock colonies were caged in groups for one week on X-disease symptomatic peach, prune, or celery plants, then transferred to celery plants for 3 or 4 weeks. After leafhoppers were removed, we sprayed the plants with dimethoate insecticide (Cygon® 50% wettable powder) immediately and again after 2 weeks. The plants were then monitored for disease symptoms over a 2-3 month period. The greenhouse was under constant positive air pressure from charcoal-filtered, heated (usually 20-26°C, occasionally to 36° during very hot days) airflow to exclude insects entering from the outside. X-MLO transmission rates to celery were determined for leafhoppers that had survived 3 weeks after an exposure on a diseased plant by individually caging the leafhoppers on small celery test plants. The insects were transferred to fresh test plants weekly for 4 or more weeks or until all the insects had died. Control insects from stock colonies were not exposed to X-diseased sources. Throughout the experiments reported here, no transmissions were noted from control plants or from plants monitored periodically to test for the potential infectivity of stock colonies.

The X-disease isolate or strain we designated as PPX originated from a laboratory transmission trial in which pear psylla (Cacopsylla pyricola [Foerster]) collected from a Yuba County peach orchard in 1982 were confined on a peach seedling. The peach test plant developed symptoms of peach yellow leaf roll disease and had a distinctive pattern of hybridization to different X-MLO DNA clones (Kirkpatrick, unpublished). Transmissions from this isolate in peach (propagated by grafting to peach) to celery were made in 1986 with C. montanus and F. florii. The X-disease isolate we designated SX was transmitted to celery from stock F. florii fed for 1 week on a prune tree in Suisun Valley, California in August, 1987. The tree had been identified as positive for X-MLO using an enzyme-linked immunosorbent assay (ELISA) for X-MLO (3). The isolate designated as GVX was transmitted to celery by stock C. montanus fed on a sweet cherry tree near Stockton, California in 1985.

Serological and DNA-DNA hybridization assays for diagnosis for the presence of X-MLO were made on plant tissue samples (usually fruit stems but occasionally leaves' midribs) as previously described (3).

RESULTS AND DISCUSSION

The origin, distinctive symptoms and serological reactions of the isolates of X-MLOs are summarized in Table 2. The main symptoms of X-disease in celery: root necrosis and dieback, following or accompanying foliar chlorosis and brittleness, were generally similar for all 3 X-disease isolates and differed chiefly in the severity or intensity of symptoms. These differences were greatest between GVX and PPX (Table 2). With GVX, necrosis

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of the smallest roots preceded foliar symptoms by at least several days. In warm conditions (>30°), such plants often wilted before any leaves became chlorotic. In order to select plants for leafhopper acquisition feeding, the roots had to be examined periodically to identify infected plants because plants often died within 3-5 days after the first foliar symptoms appeared. Root growth never reappeared in GVX plants after roots began to die. In contrast, smaller roots of PPX celery plants died back, but some living roots always remained. Celery plants with the PPX strain remained alive for more than 2 years, whereas GVX celery did not live beyond 10 weeks under normal greenhouse conditions. Transplanted offshoots of PPX-symptomatic celery grew to near normal size, although the mass of living root and shoot tissues was always less than healthy plants. Unlike GVX and SX, the youngest leaves of celery with PPX appeared to be normal in size and color and became chlorotic several weeks after emergence.

GVX strain of X-MLO was transmitted with the highest efficiency; PPX and SX were transmitted at very low efficiencies (Table 3). In the initial recovery of SX from prune, only one of 16 surviving *F. florii* transmitted to celery. In the first passage of SX from celery to celery, two groups of *C. montanus*, numbering 50 in all, failed to transmit. In the second passage from celery to celery, none of *F. florii* transmitted. Thus in all 3 transmission trials, the transmission efficiency of SX was below 10% per week per insect. Such low rates as exemplified by strains PPX and SX may be more typical of isolates from natural field infections in contrast to the much higher transmission rates reported (1,2,3,9) for X-MLO strains maintained for long periods via leafhopper transmission. The GVX isolate was also transmitted at much lower rates than another isolate (1) from the same area (Stockton-Linden).

Temperature, vector biotype and other factors can effect transmission efficiencies with a particular vector-pathogen-plant system (1). Our own trials were conducted at different times of the year under greenhouse insectary conditions, but insectary temperatures during these transmission assays were close to optimum. Low vector transmission rates (<5-10% per week) such as encountered with PPX and SX would still be consistent with the low densities of potential vectors estimated from vector surveys and resultant rates of spread of X-disease recorded in California (5,6,7).

Our observations further document considerable variability among MLO isolates associated with a disease such as X-disease of stone fruits. How much variation is attributable to regional or symptom-based "strain" differences and how much variation is normal among isolates having the same syndrome or from the same region has not yet been estimated.

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Table 1.
Characteristics of strains of X-disease from California (2)

Strain	Locality	Distinguishing Symptoms
Green Valley	Sacramento delta	peach leaves reddened, with irregular necrotic lesions; does not kill *P. avium* rootstocks
Napa Valley	Napa and Sonoma Counties	normal length cherry fruit peduncles; kills *P. avium* rootstocks
Peach yellow leaf roll	Butte, Sutter, Yuba Counties	peach leaves yellowed, cupped abaxially, with "swollen" veins

Table 2.
Sources of X-MLOs used for transmission studies, 1987-88

X-disease source (and date of collection)	Distinctive symptoms	Serological reaction (ELISA)[x]
GVX		
cherry with buckskin disease, Stockton (1985)	kills celery in 6-10 weeks at 20-26°C; incubation period 4-6 weeks	+++
SX		
Fieberiella florii transmission from prune, Suisun (1987)	moderately virulent to celery roots; incubation period 5-8 weeks	+++
PPX		
peach inoculated by pear psylla	all roots never killed; incubation 8-10 weeks from Yuba County (1982)	+

[x]/+++ = strong positive reaction; + = weak positive reaction in ELISA of celery midribs.

Table 3.
Transmission of X-MLO isolates to celery by *Collandonus montanus* and *Fieberiella florii*

	Transmission efficiency[x]	
X-MLO Strain	C. montanus	F. florii
GVX	27/87	2/24
SX	2/64	1/13, 0/12
PPX	0/30[y]	1/53

[x]Numerator is the number transmitting during the week of peak transmission. Denominator is the number of insects alive the same week.

[y]Groups of 50 and 55 *C. montanus* each transmitted to two successive plants.

UNCERTAINTY IN THE EARLY DETECTION OF TOMATO RING SPOT VIRUS IN PEACH

J.M. Halbrendt, C.A. Powell and B.A. Jaffee

ABSTRACT

Seventy-two peach trees (Prunus persica (L.) 'Redskin'/'Halford') were planted under three population levels of Xiphinema americanum (sensu lato) and four levels of dandelion infected with Tomato Ring Spot Virus (TmRSV). In the fifth growing season 13 trees (18%) were identified as showing poor growth although without the classic symptoms of Peach Stem Pitting (PSP), these were primarily trees growing under high nematode - high dandelion levels. Root tissue of all 72 trees was tested by enzyme linked imunosorbent assay (ELISA) for TmRSV on 8/30/88 and again on 9/1/88. Results of both tests were identical and identified 35 of the 72 trees (49%) as positive for TmRSV which included 11 of the 13 trees showing poor growth. Although the ELISA test appeared to work well the high number of TmRSV infected trees was not anticipated. Future testing of these trees and documentation of the spread of PSP in the orchard will help answer questions regarding these results.

TmRSV infected peach trees eventually develop PSP which is characterized by chlorosis, reduced growth, and pitting of the root tissue below the scion/root union. Infected trees usually decline rapidly and die once these diagnostic symptoms appear (5). Xiphinema spp. vector the virus from broadleaf weeds (especially dandelion) to peaches and other stone fruit (1,2). Although the basic relationship between virus, nematodes, weeds and peaches is understood (3,4), many questions remain regarding the interactions of these organisms as they relate to control of PSP in the orchard. This study was initiated to relate the incidence of PSP in the orchard to Xiphinema spp. population levels and numbers of TmRSV infected dandelions.

MATERIALS AND METHODS

Nematicides were used to establish three different population levels of Xiphinema in orchard plots (64 ft x 14 ft). Treatments included fumigation with Vorlex® (20 gal/acre) plus postplant applications of Vydate® (6 lb/acre) (low level), postplant applications of Nemacur® (9 lb/acre) (moderate level) or no nematicide (high level). The fumigant was applied in the fall of 1983; Vydate and Nemacur treatments were applied each spring thereafter. Four peach trees were planted in each plot in the spring of 1984. Superimposed on nematode levels were 4 levels of dandelions infected with TmRSV; 0, 1, 6 or 12 plants per tree. The 3 nematode levels and 4 dandelion levels were arranged in a split-plot randomized complete block design with six replications (72 trees total).

Xiphinema population levels were determined twice a year (spring and fall). Nematode counts were made from composite soil samples, four cores each, taken from beneath each tree. Trunk diameters were recorded each fall and measurements of terminal growth began in 1987. In addition, a subjective evaluation of tree vigor was also made. In August 1988, a root sample from each tree was tested for TmRSV. A Tekmar tissumizer was used to macerate approximately 0.3 g. of feeder root in 5 ml. PBS buffer for 10 s. The supernatant was then used for the ELISA test. The test was repeated two days later with the same root material.

RESULTS AND DISCUSSION

Nematode counts taken over five years show that although populations fluctuated, the nematicide treatments were effective in maintaining three levels of feeding pressure on the trees (Fig. 1). Nematode population levels averaged approximately 15, 5, and <1 nematodes/100 cc soil for the high, moderate and low levels respectively.

When the corresponding dandelion numbers for each tree were assigned to the data from nematode counts, the three population levels remained consistent except at the 12 dandelion level where high and moderate nematode levels were nearly the same which may be due to sampling error (Table 1). It should also be noted that although three distinct population levels were evident, a comparison of population means did not separate the low and moderate levels at the 95% level.

All trees appeared healthy through the 1987 growing season and no obvious differences in tree growth were observed. Evaluation of the orchard on 6/28/88, however, indicated that 13 trees showed signs of relatively poor growth. This observation was not supported by a comparison of increases in terminal shoot length but was supported by the relative amount of trunk cross-sectional area increase (Fig. 2). Figure 2 shows the total trunk cross-sectional increase (cm^2) recorded for the trees from 1984 to 1986 (6 trees/treatment). Trees growing under conditions of low nematodes and few dandelions were uniform while most of the trees showing poor growth were growing under conditions of high nematodes and many dandelions.

It was suspected that trees showing visible indications of reduced vigor were infected with TmRSV. Serological testing to confirm this hypothesis resulted in a positive TmRSV reaction for 11 of 13 showing poor growth and also for 24 of the remaining 59 trees that appeared healthy (Table 2). This test was repeated with the same root sample and identical results were obtained. While some false positive and false negative reactions

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may occur with ELISA, the high number of unanticipated positive reactions raises some questions about the spread of TmRSV in this orchard plot and/or the reliability of serological testing. Two possible explanations for these results are proposed. Perhaps there is a compound present in some peach root samples (but not all) which will react to give a false positive ELISA test for TmRSV or perhaps trees testing positive for TmRSV are actually at an early stage of infection and do not yet show indications of being stressed. These trees will be tested each year for TmRSV and monitored for the appearance of diagnostic PSP symptoms in an attempt to resolve these questions.

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Table 1.
Mean number of Xiphinema/100 cc soil recovered from three nematicide treatments and four dandelion levels averaged over five years.

Dandelion Level	Xiphinema Population Level High	Moderate	Low
0	14.3 bA†	4.7 bB	0.8 aB
1	14.4 bA	5.4 bB	0.5 aB
6	20.0 aA	4.0 bB	0.6 aB
12	10.1 bA	8.9 aA	0.6 aB

†Means within a column followed by the same lower case letter or means within a row followed by the same upper case letter are not significantly different (P = .05) by Fisher's LSD.

Table 2.
Results of rating trees for vigor, and serological testing for TmRSV.

Xiphinema Population Level	0	1	6	12
Low	0/6†	0/6	1/6	0/6
	2/6††	3/6	2/6	4/6
Moderate	0/6	0/6	0/6	1/6
	2/6	2/6	4/6	2/6
High	0/6	2/6	6/6	3/6
	1/6	4/6	5/6	4/6

†Top row for each nematode level shows results of tree rating on 6/28/88. (Number of trees showing poor growth/number of trees in treatment.)

††Second row for each nematode level shows results of ELISA test for TmRSV on 8/30/88 and again on 9/1/88. (Number positive for TmRSV/number of trees.)

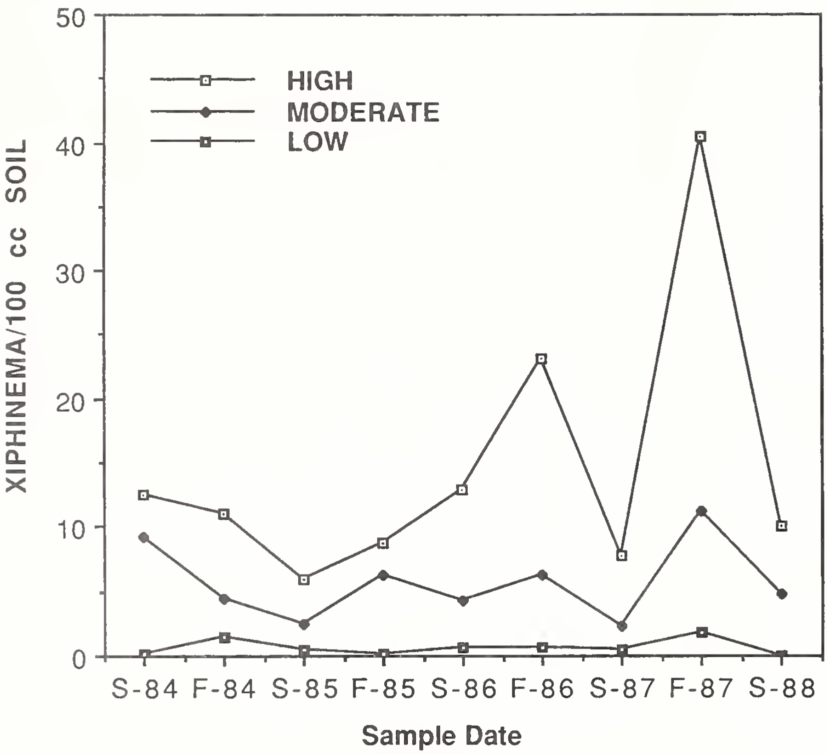

Figure 1. Mean number of Xiphinema/100 cc soil recovered from three different nematicide treatments (24 trees/treatment) over five years.

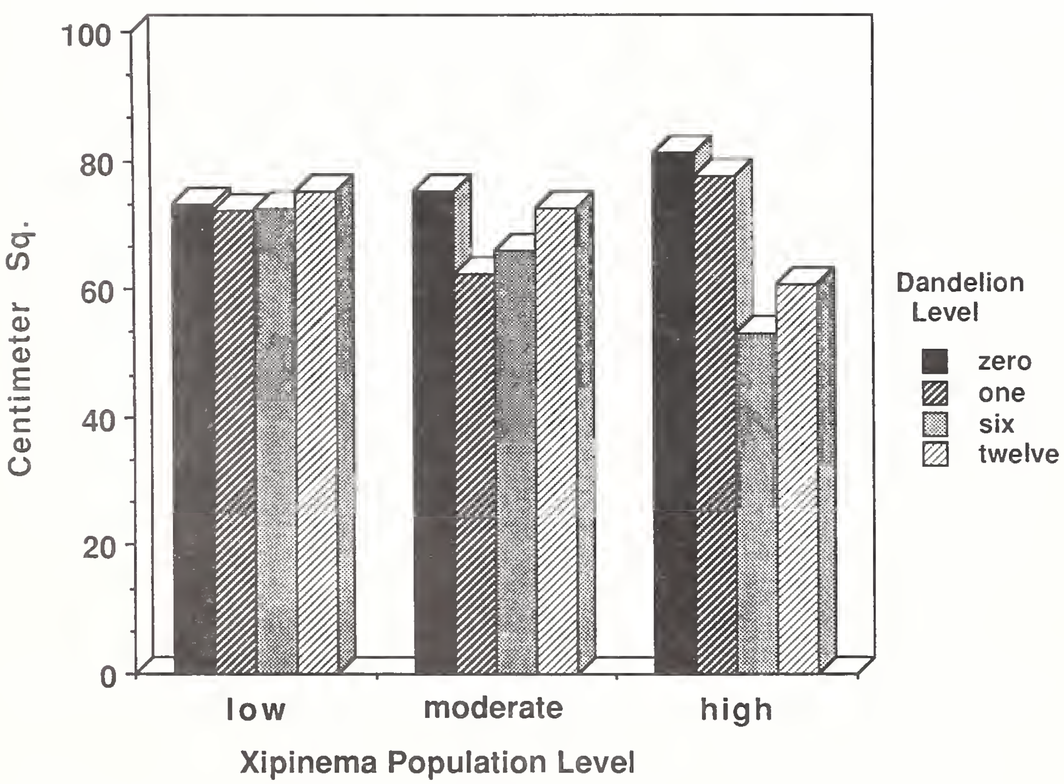

Figure 2. Total trunk cross-sectional area increase (cm^2) for peach trees at three Xiphinema population levels and four dandelion levels over five growing seasons 1984-1988.

Nematode Session

DEVELOPMENT OF PEACH TREE SHORT LIFE IN FIELD MICROPLOTS AS RELATED TO PRESENCE OF CRICONEMELLA XENOPLAX AND PRUNING TIME

A.P. Nyczepir and R.R. Sharpe

ABSTRACT

Twenty-four field microplots were established with 'Nemaguard' peach cuttings in May 1984 to determine the interrelationship between pruning time, Criconemella xenoplax (Cx) and the development of peach tree short life (PTSL) over time. Soil in plots had not been previously associated with peaches and was preplant fumigated with methyl bromide prior to inoculation with Cx. Experimental design was a 2 x 2 factorial in a completely randomized block. It consisted of two Cx treatments (inoculated and uninoculated) and two pruning treatments (December [DP] and March [MP]). Treatments were applied in 1985. In 1986 and 1987, one DP Cx-inoculated tree died from PTSL. In 1987, one each of DP and MP Cx-inoculated tree died from water-logging. By mid-March (at bloom time) 1988, the remaining three DP Cx-inoculated trees were exhibiting PTSL symptoms, whereas the other treatment trees wre not. By June 1, 1988, 100% and 60% in the DP and MP Cx-inoculated trees, respectively, succumbed to PTSL. None of the control trees in either pruning treatment died from PTSL.

Peach tree short life (PTSL) is usually associated with peach plantings on old peach sites (6). Protecting peach trees from PTSL is possible if growers follow a previously published 10-point program (1). Late winter pruning and pre- and post-plant fumigation are two practices highly recommended by cooperative extension specialists to manage PTSL. Peach tree susceptibility to PTSL is greater when pruned in October-December, as compared to trees pruned in succeeding months (2). December pruning decreases cold hardiness, vigor, and survival of trees (3). Fumigation is recommended to control the ring nematode, Criconemella xenoplax, which predisposes peach trees to PTSL (3,5). Trees in fumigated soil expressed improved vigor, increased tree survival, and increased cold hardiness (3). In spite of these recommendations, due to the time consuming task required, many peach growers in Georgia still prune in November-December.

This study was initiated to determine if an interaction exists between PTSL, pruning time, and the presence of C. xenoplax.

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MATERIALS AND METHODS

"Closed-end" field microplots (1.2 m id x 12.m deep) were established in June 1983, on a site with no historical record of having been planted to peaches (4). Experimental design was a 2 x 2 factorial in a completely randomized block. It consisted of Cx treatments (inoculated and uninoculated) and two pruning treatments (December [DP] and March [MP]). Treatments were applied in 1985. Trunk diameter (17.4 cm above soil line) and nematode populations were monitored annually and the occurrence of PTSL (as indicated by symptoms and tree death) recorded over time.

RESULTS AND DISCUSSION

Criconemella xenoplax (Cx) populations in inoculated plots were well established by 1985 and remained relatively stable throughout the study (Table 1). No other plant-parasitic nematodes were present in any of the plots and no detectable Cx contamination occurred in the controls. In 1986 and 1987 one DP Cx-inoculated tree died from PTSL (Table 1). In 1987, one DP and one MP Cx-inoculated and one DP-control plot became water-logged. The two Cx-inoculated trees eventually died, whereas the control tree recovered but was discounted from the test. The three remaining DP Cx-inoculated trees developed PTSL symptoms in March 1988. PTSL symptoms occurred earlier ($P < 0.01$) in DP than in MP Cx-inoculated trees. Trunk damage was evident at this time as indicated by the intercellular leakage and staining of the bark tissue. These trees never reached full bloom before exhibiting stress symptoms. The characteristic 'sour-sap' odor associated with PTSL was evident at this time. All five remaining MP Cx-inoculated trees appeared healthy at this time and reached full bloom status, but three trees did not set fruit and exhibited symptoms of PTSL stress as leaves developed. These trees eventually died by June 1988. In late May 1988, one of two remaining live MP Cx-inoculated trees became waterlogged. None of the control trees died from PTSL.

Mean trunk diameter between treatment trees was not different when measured in January 1988 (Table 2).

Results of this study demonstrate the harmful effect of DP versus MP in the presence of Cx over time. Even though trees died from PTSL in both DP and MP Cx-inoculated treatments, the disease occurred earlier in the DP Cx-inoculated trees.

Secondly, if Cx is controlled it does not matter what time of the year (DP vs. MP) a grower prunes his orchard. This enables the grower to have adequate time to complete his annual pruning duties without the fear of the orchard succumbing to PTSL.

Finally, this study emphasizes that 'old' peach soil is not always a prerequisite for the occurrence of PTSL. Meaning that PTSL is a "nematode" associated disease which is unique with this species since other plant-parasitic nematodes were absent. Without the presence of Cx, PTSL will not occur.

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Table 1.
Population density of C. xenoplax and development of PTSL in field microplots as related to pruning time.

	Nemas/100 cm^3 Soil[A]			% PTSL			
				December-Pruned		March-Pruned	
Year	CX	Check		Cx	Check	Cx	Check
1985	2408	0		0	0	0	0
1986	4385	0		17(1)[B]	0	0	0
1987	2208	0		33(2)	0	0	0
1988	3036	0	Mar 14	100(5)**[C]	0	0	0
			Apr 15	100(5)+	0	40(2)	0
			May 31	100(5)	0	60(3)	0

[A]Initial nematode inoculum was 5,000 C. xenoplax/plot.

[B]Number in parenthesis represents number of trees.

**[C] = P <0.1; * = P <0.05; + = P <0.08 corresponds to comparisons made between pruning treatments within inoculated plots utilizing Fisher's Exact Test.

Table 2.
Trunk diameters of four year old peach cutting grown in microplots, Byron, Georgia, January 1988.

Treatment	Trunk-Diameter ($\pm$ SD) (cm)	Number of Trees/Treatment
Cx - MP[z]	47.93 $\pm$ 5.71	5
Cx - DP[z]	49.76 $\pm$ 1.61	3
Control - MP	48.15 $\pm$ 3.63	6
Control - DP	48.21 $\pm$ 1.41	5

[z]Cx = Criconemella xenoplax; MP = March pruned; DP = December pruned.

THE USE OF GY-81 (TETRATHIOCARBONATE) IN THE MANAGEMENT OF NEMATODE AND DISEASE PROBLEMS IN STONE FRUITS

Sahag K. Garabedian and Neil Phillips, Jr.

ABSTRACT

A fall application of GY-81 applied as an irrigation injection was evaluated as a management tool for Bacterial Canker Complex and nematodes. A Bacterial Canker index developed by the University of California was used, along with yield and nematode population measurements. One month after treatment, the ring nematode population had been reduced by 74%. At the end of the experiment, no trees had died in the treated area, and only 10% of the trees showed slight bacterial canker symptoms, while 30% of the untreated control trees died and 52% of the survivors showed extensive symptoms of bacterial canker.

In addition to postplant treatments, a preplant drench of GY-81 and water was tested as a management tool for Bacterial Canker and nematodes. Shoot length, nematode population and tree survival were measured. One month after treatment, the nematode population was reduced by 93% at the high rate and 79% at the lowest. One year after treatment, the nematode population was 99% less than the control area at the high rate and 90% less than the control area at the lower rate. Additionally, treated trees had shoot growth 34% greater than the untreated control at the high rate, and 8% greater at the low rate.

Almond trees grown in soil infested with ring nematode (*Criconemella xenoplax*) are more susceptible to Bacterial Canker than trees planted in soil without ring nematodes (1). It is common knowledge that DBCP was an excellent control agent for Bacterial Canker in California and Peach Tree Shortlife in the southeast United States. Since the disappearance of DBCP, no commercially acceptable chemical alternative has been registered on almonds (and most stonefruits) for the control of Bacterial Canker or nematodes. Lesion and ring nematode have been shown to be detrimentally affecting 37% of the almonds in California (2).

This study was initiated to determine if applications of GY-81 could reduce Bacterial Canker symptoms and eliminate nematode pathogenicity.

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MATERIALS AND METHODS

GY-81 is a 31.8 weight percent aqueous solution of sodium tetrathiocarbonate, which reacts with soil to produce carbon disulfide (CS_2) as a toxicant. One litre of GY-81 contains 0.405 kg of sodium tetrathiocarbonate, and produces 0.16 kg of carbon disulfide.

Experiment I

A 2-year old orchard of "Carmel" and "Nonpareil" almond trees with nemaguard rootstock was selected as the test site.

Ten trees per replicate were used with 6 replicates for each treatment. GY-81 was applied at a rate of 460 l/ha (50 gpa), while the untreated control received water. A border irrigation system was used to irrigate the trees. Using a metering pump, the GY-81 was metered into the irrigation water over the one hour it took to irrigate the test plot. Ridges of soil were made with a tractor and implement around each ten tree replicate so that no chemical was applied to the control replicates. After the GY-81 was applied, the untreated control was irrigated.

Nematode samples were taken pre-treatment and every three to six months for two years. Yield was taken every year for three years. The Bacterial Canker index was used only in the third year.

Experiment II

A nearby peach orchard with many original trees missing was selected as the test site. The "Carson" variety on a nemaguard rootstock was planted. Trees were randomly assigned a treatment. 93 l/ha (10 gpa) and 185 l/ha (20 gpa) of GY-81 were tested versus an untreated control. The GY-81 was applied as a drench in 75 litres (20 gpa) of water per hole three days prior to planting the peach trees. Six replicates of single trees were used for each treatment. Nematode samples were taken pre-treatment with a 1-inch oakfield tube and every six months after that. Samples were taken to a depth of 45 cm (18 inches) with four cores taken from each tree. Shoot length and tree survival were measured one year after the experiment.

RESULTS AND DISCUSSION

Nematode counts in the post-plant experiment (Experiment I) were reduced consistently from 56 to 80% over a one-year period (Table 1). Bacterial Canker symptoms in the third year were devastating in the control area but barely measurable in the treated area (Table 2). Additionally, a yield increase of 34% was noted in the second year (Table 3). Although yield has not been measured in the third year, the reduction in nematode counts and reduction in Bacterial Canker symptoms should result in a significant yield increase as in the second year. GY-81 will now provide growers with a viable alternative to controlling Bacterial Canker and nematode pathogenicity.

Nematode counts in the replant experiment (Experiment II) were reduced from between 69 to 99% over the one year in which the experiment was evaluated (Table 4). The greatest control, however, was achieved after one year. A 90% nematode reduction was noted in the area treated by the low rate, and 99% reduction was noted in the area which was treated by the high rate. Treated trees were significantly larger and had more fruit on them than control trees (Table 5). In addition, two of the six control trees died, while none of the treated trees died.

Cooperating growers are encouraged by these results, as replanted trees often die within one or two years (as observed in the control area) and, if they do survive, grow very poorly. In the future, a grower will be able to do a pre-plant drench with GY-81 and then follow with post-plant treatments when warranted. Other advantages that interest growers are (a) the freedom to plant new trees 3 to 5 days after fumigating, (b) the ability to treat tree sites interplanted with older trees with no chance of phytotoxicity on adjacent older trees, and (c) GY-81 is being proven to have activity on certain fungi, especially Phytophthora sp. (3).

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Table 2.
Bacterial Canker rating* of almond trees using 0-5 scale, measured on May 24, 1988.

	Tree Replicates						
Treatment	1	2	3	4	5	6	7
GY-81 460 l/ha	0	0.6	0.7	0.7	0.3	0.3	0.43
Untreated	3.6	2.3	4.0	3.6	1.8	2.6	3.0

% Survival -- 0 - 5 Scale

0 = Perfectly healthy
1 = Blast symptoms only
2 = Hanger or branch killed
3 = Major limb death
4 = Primary scaffold dead
5 = Whole tree dead
* = Personal communication, Maxwell Norton, University of California Cooperative Extension, Merced County.

Table 3.
Average almond yield per replicate for 1986 and 1987.

Treatment	Pounds/rep. 1986	Pounds/rep. 1987
GY-81 460 l/ha	30.5	190.5
Untreated	30.3	142.0
	% Increase	
	0.6%	34.0%

Table 1.
Nematode populations over a two-year period in almonds.

Average ring nematode (Criconemella xenoplax)/250 ml soil

	Treatment Date					
Treatment	10/11/85*	4/25/86	9/8/86	11/13/86*	4/15/87	8/25/87
GY-81 (460 l/ha)	52.5	17.5	241.5	154.3	663	523
Control	49.5	65.7	545.5	506.4	1926	2060
	Percent control					
	-6.0%	74%	56%	70%	66%	75%

* = Treated 50 gpa on 10/11/85, 11/13/86.

Table 4.
Average ring nematode counts/500 ml soil over one year period in young peach orchard.

Treatment	Sampling Dates 4/13/87	5/19/87	8/28/87	3/24/88	6/13/88
GY-81 93 l/ha	100	181	116	80	58
GY-81 185 l/ha	398	60	195	8	11
Untreated	415	859	632	807	512
	Percent Control				
GY-81 93 l/ha	76%	79%	82%	90%	89%
GY-81 185 l/ha	4%	93%	69%	99%	98%

Treated 4/14/87

Table 5.
Average length of two longest limbs of young peach trees.

	Average length per treatment (cm)
GY-81 93 l/ha	44.5*
GY-81 185 l/ha	52.3**
Untreated	41.3***

* = Most trees had 3 to 4 fruit on them.
** = Most trees had 15 to 20 fruit on them.
*** = None of the trees had fruit on them and two trees died in the first winter.

NEMACUR: AN AID TO CROP PRODUCTION AND BCC MANAGEMENT IN STONE FRUIT AND ALMONDS

A.C. Scoggin

ABSTRACT

Nemacur has been evaluated on tree crops including stone fruit since the early 1970's. University and Mobay research has steadily increased over the years due to the increasing problems of peach tree short life or BCC.

Mobay and university data from North Carolina, South Carolina, Georgia, and California show Nemacur to be effective in preventing or delaying tree losses. Yields increase as a result of increased tree vigor, increased tree survival, and reduction of nematode species.

INTRODUCTION

Several researchers showed the association between the ring nematode, Criconemella xenoplax, and the bacterium, Pseudomonas syringae, cause Peach Tree Short Life or Bacterial Canker Complex. Given the current lack of resistant varieties to either the ring nematode or to the bacterium, control strategies must be directed toward one of these pests.

The most success has come from control of the nematode. Fumigation was preferred and DBCP was the best choice in established orchards until it was banned in 1979. Research on Nemacur has continued since the early 1970's, with increased effort after the loss of DBCP.

University and Mobay research has led to new Nemacur use patterns, rates, and methods of application which have increased the effectiveness of Nemacur in a PTSL/BCC management program.

PRODUCT CHARACTERISTICS

Nemacur is an organophosphate nematicide with the common name fenamiphos. It is active on plant parasitic nematode genera and has insecticidal activity, mostly on thrips and some aphid species. There is generally no phytotoxicity from soil applications except when high rates may come into direct contact with the roots, as when applied soon after transplanting before the soil has settled and plants are established.

Against nematodes, Nemacur has both contact and systemic activity. While contact activity is the primary mechanism of control, good activity after band treatments suggests excellent movement of Nemacur in the root system. A lag time of one year between Nemacur application and improved tree vigor and yield is common.

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Nemacur requires rapid incorporation for maximum effectiveness. Incorporation can be achieved mechanically, by rainfall or by irrigation. Where rainfall or irrigation may be delayed, mechanical incorporation offers protection from degradation until water moves the product to the root zone.

The parent compound has a solubility of 560 ppm at 20°C. The nematicidal metabolites (Nemacur sulfoxide and sulfone) are both more soluble than the parent compound. The sulfoxide is the most soluble. Oxidation from the parent compound to the sulfoxide is rapid. The active half-life of Nemacur on mainland soils averages one month, but there is considerable variation with temperature, pH, and other conditions.

Nemacur and it's degradation products are moderately adsorbed on sandy loam or silt loam soils and are more strongly adsorbed on soils with higher organic matter. It is classed as Class 2 of 5 classifications of increasing soil mobility and therefore is regarded as having "low mobility."

PERFORMANCE SUMMARY

Almonds:

Nemacur was used in band applications on Nonpariel and Mission almonds in three separate field tests. Rates were 9 lbs. (one test) and 10 lbs. (2 tests) active ingredient per treated acre per application. Band widths were 45-46% of the field for a total field acre rate of 4.5 lbs. active ingredient.

Control of ring nematode averaged 62.4% four to twelve months after application. Yields averaged 28.8% higher than the check.

A trial to evaluate re-plant survival in a heavily infested ring nematode/BCC field was conducted by Dr. Michael McKenry. His results showed an 18 lb. AI/A application applied in October increased tree survival from 22% in the control to 100%. A July application at the same rate increased tree survival to 72%. A split application of 9 lbs. in July and 9 lbs. in October increased tree survival to 100%.

On established trees, spring applications were shown to reduce nematode counts, improve vigor, and increase yields in stressed orchards. However, for improved tree survival, fall applications were superior to mid-summer treatments.

Registration on almonds is not expected for two to three years. Mobay is currently collecting residue samples required for this use and will submit for registration when the required tests are complete.

Peaches:

Research by Zehr, et al. (3), Ritchie (2), Miller, et al. (1), and other researchers have shown the potential of Nemacur in a peach tree short life or BCC management program. The number of trees dying from PTSL/BCC were reduced significantly where Nemacur was used. In several tests few or no Nemacur treated trees were lost where up to 80% of untreated trees died.

While single applications have depressed nematode numbers and increased tree vigor and survival, multiple applications have given superior control. The best method to increase tree survival is one or two fall applications followed by one spring application. The fall applications are important for tree survival, while spring treatments seem to provide better yields.

Band applications have been used to reduce grower costs and environmental exposure. Band widths near 50% of the row spacing are needed for mature trees grown under conventional irrigation or natural rainfall conditions. Further reductions to band widths to 15-25% of the field area are possible for smaller trees, and trees grown under low pressure irrigation.

Experiments show low pressure irrigation injection (drip, trickle, or mini-sprinklers) is the most effective method offering simultaneous application and incorporation. This method is cleared everywhere except in California, where registration is expected prior to the 1989 growing season.

Plums/Prunes:

Very little information is available on the magnitude of the PTSL/BCC problem on these crops. California growers requested a Section 18 exemption to allow Nemacur use (expires 9/1/88). This suggests a problem exists.

Nemacur has shown good control of ring nematode in Mobay testing and control of lesion and pin nematode in university testing using the same rates and methods as discussed in peaches.

Residue trials are in progress, and, as with almonds, registration is not expected for another 2-3 years due to studies yet to be completed and the lengthy agency review process.

SUMMARY

Until biological or cultural methods are developed to reduce the impact of BCC in stone fruit and almond production, Nemacur can be successfully used to reduce tree loss and increase tree vigor and yields.

Registered rates are 6-2/3 gls. of Nemacur 3 and 133 lbs. of Nemacur 15G (20 lbs. AI) per treated acre. The total amount used per field acre can be reduced by using band applications without loss of effectiveness. Band widths should be 50% of the row spacing for mature trees, but can be reduced in young orchards with smaller trees, or where low pressure irrigation is used.

The best application timing for reducing tree losses is for applications to be made in the fall and spring. Fall only treatments were generally superior to spring-only treatments, and multiple treatments were much better than single treatments. When properly applied, tree loss has been reduced significantly with some studies showing 100% survival where 25-88% of control trees were lost.

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THE EFFECT OF FENAMIPHOS ON BACTERIAL CANKER COMPLEX

Maxwell Norton

MATERIALS AND METHODS

A four-year study was undertaken to determine the effects of Fenamiphos (Nemacur 3) on Bacterial Canker incidence in mature bearing peaches under drip irrigation. A mature block of O'Henry peaches, half planted in 1977 (2 reps) and half planted in 1979 (2 reps) on S-37 rootstock under drip irrigation was selected. The site was previously planted to peaches and had a history of Bacterial Canker problems. The soil series for the entire site was Delhi sand. Treatments began May 1986.

Treatments:

10 lb. ai/treated-acre** in May
10 lb. ai/treated-acre** in October
5 lb. ai in May + 5 lb. ai in October
Check

** Treated-acres were assumed to be 50 percent of the field-acres. Four 2-row, 84-tree reps per treatment, randomized, complete block design.

The material was injected through the drip system over 30 minutes, followed by a 6-12 hour irrigation.

RESULTS

In 1987, disease incidence was minimal, but in 1988 ratings were made for both Bacterial Canker incidence and severity, and a symptom we called "stress gumming." The following disease rating symptom was developed with the assistance of Dr. Beth Teviotdale, Cooperative Extension Plant Pathologist:

Rating	Symptom
1	Blast symptoms to flowers or shoots
2	Significant damage to or death of branch or hangar
3	Significant damage to or death of a limb
4	Significant damage to or death of a 1° scaffold
5	Death of whole tree

An incidence value was derived by tallying the number of trees with a severity rating of 1 or more.

$\overline{X}$ incidence of trees exhibiting symptoms:

Check	5.0 a
May & October	3.0 a
May	2.75 a
October	1.5 a

$\overline{X}$ incidence of trees with a symptom rating of 2 or more:

May & October	6.25 a
Check	3.75 a
May	2.25 a
October	1.5 a

"Stress gumming" is a symptom where gumming is observed up and down the trunk and primary scaffolds, but not due to sunburn or borers, and not originating from cankers.

Severity value:

Check	9.25 a
May & October	7.25 a
May	6.0 a
October	3.0 a

A severity value for each rep was obtained by summing all the symptom rating values observed.

$\overline{X}$ Number of trees with stress gumming:

May & October	30.25 a
Check	26.25 a
May	22.0 a
October	19.75 a

Due to high replicate variability, none of the treatments were statistically significant. There does not seem to be a trend and subsequent observations may confirm this.

Besides taking additional disease observations in 1989, we intend to measure yield differences as well.

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GREEN MANURING WITH MARIGOLD TO CONTROL ROOT LESION NEMATODE IN AN ORCHARD

M.V. McKenry

ABSTRACT

A population of Pratylenchus vulnus was reduced by 50% to 90% for six months after 15,680 kg/ha of fresh marigold refuse was incorporated and irrigated into a plum orchard. Paratrichodorus minor was acutely susceptible to the treatment but nematode counts rebounded within four months. Paratylenchus hamatus was only marginally affected by the treatment. Plum yields collected eleven months later indicated a slight phytotoxicity associated with the treatment. Based on anticipated yields as a result of the nematode reduction the phytotoxicity was estimated to be approximately 12 to 17%.

MATERIALS AND METHODS

Our study was conducted in a 2.2 ha plum orchard located at the Kearney Agricultural Center, Parlier, California. The 10-year-old orchard is the site of a long-term study of root lesion nematode pathogenicity to plum and peach rootstocks (1). Trees are planted on a 5.4 m grid with 15 trees per row. Peach rootstock consisting of Nemaguard and Lovell and plum rootstock consisting of Marianna 2624 and Myrobalan 29C are randomized among each pair of rows. Some row pairs were inoculated in 1976 with P. vulnus and other row pairs had gradually become infected with P. vulnus by 1985. Among 8 adjacent rows we were able to identify 2 distinct population levels of P. vulnus on peach and 2 distinct population levels on plum rootstock. All rootstocks had been grafted to Friar plum in 1976.

On August 7, 1987 two treatments were imposed in the orchard including:

1) Addition of 15,680 kg/ha fresh, mature Tagetes patula cv. Janie followed by rotovation of the surface 10 cm of soil and then immediately followed by irrigation with 10 cm of water.

2) Untreated. Treatment sites consisted of 3 trees each. Post-treatment soil samples were collected from among treatment sites with use of an oakfield tube. Seven subsamples were collected from a 60 cm depth around each site. Soil samples were extracted using a Cobb sieve-mist extraction method (2). Data are reported as nematodes extracted, and the extraction efficiency is approximately 35 to 50%.

Associate/Extension Nematologist, University of California, Riverside; stationed at Kearney Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA 93648.

On July 20, 1988 all the trees were individually harvested. Six fruit size categories were obtained by passing subsamples from each treatment of fruit over a fruit sizer.

RESULTS

Population levels of root lesion nematode, P. vulnus were reduced by 50% to 90% for up to 6 months by incorporation/irrigation of marigold refuse (see Table 1). By the ninth month nematode populations in the treated sites had returned to levels similar to the untreated. The most sensitive nematode to the treatment was Paratrichodorus minor where populations were reduced by 95% 15 days after treatment. However, nematode population levels had rebounded within 4 months. Population levels of Paratylenchus hamatus were reduced slightly by the treatment and only for a short time period (3 months). Whether initial populations of P. vulnus had been established for 10 years or 3 to 4 years the treatment effect was similar.

There were no visual symptoms of improved or impaired growth associated with the treatments. Eleven months after treatment our first yield data were collected and they are presented in Table 2. In three of four rootstock-nematode combinations the green manure treatments resulted in yield reduction. In the most damage-susceptible sites (Peach rootstock with high counts of P. vulnus) yields were similar among treated and untreated, but anticipated yield benefits due to nematode control were unrealized. Yield reductions were slightly higher on the more shallow rootstock of Marianna 2624 than on the deeper Nemaguard rootstock but not significantly. There were no fruit size differences among the treatments.

DISCUSSION

Prior to initiation of this experiment we had collected plum yields from this orchard and documented a 16% to 8% yield loss due to P. vulnus on peach rootstock and plum rootstocks, respectively (1). On one portion of this site we had previously conducted a 2-year study of Nemacur® treatments compared to in situ growing and incorporating of marigold without a follow-up irrigation. From these data we were able to show a 17% yield benefit from the 2 years of Nemacur which reduced populations of root lesion nematode by 75% over 18 months and no yield benefit or nematode reduction from the incorporated marigold refuse (unpublished, McKenry). In another test we learned the value of post-treatment irrigation on marigold refuse and our expectation in this test was to have a yield improvement of 4 to 8% among the plum rootstocks and 8 to 16% among the peach rootstock depending on initial population levels of P. vulnus. Table 2 indicates that we were short of our expectation by 12 to 17%. The single rootstock -P. vulnus combination which provided no apparent loss was the combination of the most susceptible root coupled with the highest root lesion population. Our conclusion is that with incorporation of marigold refuse followed immediately by irrigation sufficient to carry any

extracts 60 cm deep we are able to achieve adequate control of P. vulnus but the phytotoxicity associated with the treatment is approximately 12 to 17% which nullifies any benefits achieved from the treatment. Similar field tests are underway elsewhere employing reduced treatment levels with a water extract of marigold. One of the characteristics of extracts from green manure is their ability to deplete oxygen from water (3). Another characteristic is that marigold specifically contains numerous carbon-sulfur compounds which may be directly phytotoxic when applied to fields at these relatively high rates. Since the marigold refuse was transported to the treatment site, yield losses were not due to competitive effects of growing a cover crop among the trees. It is clear after only a single year of treatment that phytotoxic agents are released by the incorporation/irrigation of marigold refuse. A recent report from New York indicates that biocidal activity in marigold refuse is sufficient to reduce losses caused by apple replant disease by 98% (4). Studies are currently underway to reduce treatment rates, minimize phytotoxic components through various extraction processes, and evaluate extracts from other plants.

Table 1.
Population levels of P. vulnus as influenced by rootstock and initial population levels following treatment with Marigold refuse.

Rootstock	Nematode Pi[1]	Treatment	DAYS POST-TREATMENT[2] 15	30	45	60	75	100	150	260
Peach	300	T	208	185	89	207	165	153	176	185
		U	298	565	360	463	572	289	438	147
Peach	150	T	44	33	24	21	25	63	93	60
		U	403	135	278	208	240	196	268	74
Plum	150	T	62	54	39	71	46	153	52	169
		U	124	260	297	149	182	289	167	113
Plum	75	T	27	24	16	19	8	28	25	22
		U	28	23	192	210	86	54	49	7

[1]Initial population (Pi) was based on average from 200 soil samples collected from 1986 through 1987.

[2]Extracted P. vulnus/250 cm^3 soil sample averaged from 4 replicates whether treated (T) or untreated (U).

Table 2.
Yield and anticipated yield of peach and plum rootstocks at 2 nematode population levels as influenced by treatments with marigold refuse.

	1988 Yields in kg/tree of Total Fruit: Peach Rootstock		Plum Rootstock	
Pi	300	150	150	75
Yield from untreated	119 kg	126	141	139
Yield from treated	121	119	131	120
Anticipated yield[1]	138	136	152	145
Shortfall[2]	12%	12.5%	14%	17%

[1]Anticipated yields are based on complete correction of nematode caused losses of 16% and 8% in peach and 8% and 4% on plum.

[2]Shortfall calculated from: $\% = \frac{\text{Anticipated} - \text{Actual}}{\text{Anticipated}} \times 100$

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SUPPRESSION OF THE NEMATODE CRICONEMELLA XENOPLAX WITH ORCHARD VEGETATION

Eldon I. Zehr, Daryl P. Whittington and Janet M. Scott

The ring nematode Criconemella xenoplax (Raski) Luc and Raski is an important parasite of peach trees [Prunus persica (L.)] in many parts of the United States (5,6,7). Although several chemical nematicides are effective for reducing populations to low levels (9), such treatments are costly and many growers are unwilling or unable to apply chemicals at the rates and frequency needed to control these nematodes effectively. Progress is being made to identify in Prunus sources of genetic resistance that might be used for improvement of rootstocks (2), but genetic resistance is not likely to be useful to control these nematodes in the immediate future.

Recently, Zehr et al. (8) reported that two common orchard cover crops, tall fescue (Festuca arundinacea Schoeb.) and perennial ryegrass (Lolium perenne L.), can support populations of this nematode. Concern that nematode reproduction or cover crops might add further stress to peach trees has led to warnings against the use of these plants in orchards where C. xenoplax thrives. More recent research has shown additionally that many legumes are good hosts for C. xenoplax (10). These findings have prompted us to study alternative plants that might be useful cover crops in peach orchards. We report here studies of C. xenoplax populations when buckhorn plantain (Plantago lanceolata L.) and nimblewill (Muhlenbergia schreberi J.F. Gmel) are interplanted with peach trees.

MATERIALS AND METHODS

Microplots ca. 0.85 m in diameter were established in Lakeland sand (89% sand, 6% silt, 5% clay) at the Sandhill Research and Education Center near Columbia, SC. Walls of the microplots were constructed of fiberglass sheets buried to a depth of 0.8 m. Root penetration below that depth was unimpeded. The soil was naturally infested with C. xenoplax but few other nematode parasites of peach were present.

Two experiments were established--the first in naturally infested soil without chemical treatment, and the second in soil first fumigated with 0.4 kg methyl bromide per plot applied under a tarp. Nemaguard peach seedlings were grown in the greenhouse in Lakeland sand treated with aerated steam at 60 C for 1 hour. Seedlings 20-25 cm tall were transplanted directly into the naturally infested soil or inoculated first with 500 C. xenoplax per plant 1 month before transplanting into the fumigated microplots.

After planting, the microplots were weeded by hand for the first 2 years. Supplemental water was provided by drip emitters supplying ca. 3.8 liters of water per hour. Fertilizer as 10-10-10 N-P-K was applied as needed to maintain healthy growth.

When the trees were 2 years old (1985 and 1987 for the first and second experiments, respectively), seedlings of the test plants were transplanted from flats where they had grown in the greenhouse, or the microplots were seeded directly by hand. Just before planting, four subsamples of soil per plot were collected to a depth of 15 cm with a stainless steel sampling cone to establish the initial population. Subsamples were combined, mixed thoroughly, and extracted using a semiautomatic elutriator (1) combined with centrifugal-flotation (4). Nematodes (adults and juveniles) from 100 cm^3 of soil were counted at 34X magnification.

Test plants were centipedegrass (Eremochlea ophiuroides (Munro.) Hack.), goosegrass (Eleusine indica (L.) Gaertn.), sicklepod (Cassia obtusifolia L.), marigold (Tagetes erecta L. and T. patula L.), and buckhorn plantain (Plantago lanceolata L.) in the first experiment and nimblewill (Muhlenbergia schreberi J.F. Gmel), hard fescue (Festuca ovina var. duriuscula (L.) Koch), bracted plantain (Plantago lanceolata (Michaux.), and Florida pusly (Richardia scabra L.) in the second. Fallow soil weeded by hand served as a control in both experiments. Each planting was replicated seven times in a completely randomized design.

Following establishment of the test plants, each microplot was sampled at monthly intervals for 2 years in the first experiment and for 1 year in the second (this experiment is still in progress). Four subsamples per plot were collected and extracted as described previously.

RESULTS AND DISCUSSION

Most plants tested were not suppressive of C. xenoplax in microplots (some examples are shown in Tables 1 and 2). However, buckhorn plantain in the first experiment and nimblewill in the second had consistently lower populations than the fallow control (Tables 1 and 2) and on several sampling dates the differences were significant at P = 0.1 or greater. Marigold, which has been reported to suppress Meloidogyne in some experiments (3) did not significantly affect populations of C. xenoplax in association with peach roots. Marigolds were difficult to establish and grew poorly in the shady environment of microplots. They would not appear to have significant potential for control of C. xenoplax or as a ground cover in fruit orchards.

Except for marigold and sicklepod, a noxious weed, the other plants tested have potential for use as ground cover in peach orchards. Some disadvantages observed were lack of competitiveness for both buckhorn plantain and bracted plantain, lack of

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drought tolerance for hard fescue, ineffective re-establishment the second year and inactivity during winter months for goosegrass and Florida pusly.

In the Southeast, C. xenoplax is active during winter months; thus, continued suppressiveness during the winter would be especially advantageous for a ground cover plant. Buckhorn plantain and nimblewill were suppressive during winter months in the experiments reported here. Nimblewill appears to be a more promising candidate because its vigorous growth and drought tolerance probably would enable it to maintain dominance in orchard vegetation. Buckhorn plantain, in contrast, probably would require the use of a selective herbicide to permit it to flourish in an orchard environment. Both of these plants seem to deserve further study as ground cover in peach orchards.

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Table 1.
Populations of *Criconemella xenoplax* associated with 'Nemaguard' peach seedlings interplanted with centipedegrass, 'Pumpkin Crush' marigold, or buckhorn plantain in microplots, May 1985-July 1987.

Peach interplanted with:	C. xenoplax/100 cm^3 soil on:												
	5/21 (Pi)	7/11	7/30	8/30	9/30	11/7	12/5	1/7	2/7	2/28	3/28	4/29	5/30
Centipedegrass	377[a]	433	685	357	1112	2383	1030	1747	1045	1511	1542	598	1061
Marigold	611	746	1047	946	498	2393	578	734	652	759	841	259	402
Buckhorn plantain	561	177	298	285	287	723	485	330	284	259	210	74	172
Control	492	333	444	510	218	982	672	583	345	538	285	167	845
	7/8	7/28	9/4	10/1	11/7	12/4	1/5	2/2	3/4	4/	5/8	6/10	7/13
Centipedegrass	643	208	314	498	1111	895	1157	765	571	644	514	255	640
Marigold	333	191	383	485	866	1039	805	841	629	706	325	122	429
Buckhorn plantain	122	72	260	233[b]	364[c]	660[c]	396[c]	485[b]	297	261[b]	211	50	254
Control	637	478	249	1148	2526	1756	1464	1226	951	682	420	188	881

[a]Average of seven replicates.

[b]Significantly different from the control at $P = 0.1$.

[c]Significantly different from the control at $P = 0.05$.

Table 2.
Populations of *Criconemella xenoplax* associated with 'Nemaguard' peach seedlings interplanted with Florida pusly or nimblewill, June 1987-June 1988.

Peach interplanted with:	C. xenoplax/100 cm^3 soil on:												
	6/23 (Pi)	7/20	8/21	9/17	10/30	11/29	12/30	1/28	2/25	3/22	4/29	5/27	6/28
Florida pusly	881[a]	424	301	416	358	193	289	337	205	186	--[b]	--	--
Nimblewill	420	500	86	105	282	159	152	103	114	136	89	70	107
Control	574	658	127	168	560	424	188	339	210	197	445	178	229
Probability of difference[c]	.23	.22	.75	.62	.03	.04	.89	.08	.45	.65	.02	.68	.37

[a]Average of seven replicates.

[b]Sampling discontinued due to poor re-restablishment in spring.

[c]Probability nimblewill versus control.

CRICONEMELLA XENOPLAX: QUANTIFYING NEMATODE STRESS TO TREES

H. Ferris, B.A. Jaffee, A. Juurma and M.V. McKenry

INTRODUCTION

The ring nematode, Criconemella xenoplax, predisposes Prunus spp to bacterial canker caused by Pseudomonas syringae and contributes to tree decline and mortality in the San Joaquin Valley of California. The problem is more severe when population densities of ring nematodes are high than when densities are low (1), but the quantitative relationships between nematode densities and tree yield or mortality are not known. Such relationships are not easily determined in perennial crops and are confounded by annual growth cycles, complex plant phenology and previous growth and stress history of the crop. Noling and Ferris (2) approach this problem in alfalfa by using a multiple point model that measured the rate of increase of nematode stress dosage to the crop, similar to the cumulative nematode density assessment used by Ritchie (3). To obtain measurements of the impact of management on the nematode stress dosage, and its effect on tree yield and mortality, it was necessary to design an experiment utilizing different management approaches (rootstocks and nematicides) that would allow economic analysis.

The objectives of this study were to examine the population biology of the ring nematode on Lovell and Nemaguard rootstocks; to obtain parameter values for the relationship between tree mortality and yield loss, and the nematode stress dosage, through time; and to examine the economics of nematode management relative to the benefit derived from tree longevity and yield increase.

MATERIALS AND METHODS

The orchard site was a loamy sand/sand in the area of Livingston, California that had previously been planted to peaches. The orchard was ripped and preplant fumigated in the tree rows with Telone 2 nematicide in the fall of 1984. It was planted in February, 1985 to Halford peach on alternating four-row strips of Lovell and Nemaguard rootstock. The orchard is drip irrigated, allowing application of nematicides through dripper lines and the maintenance of non-nematicide checks by closing valves in the dripper line. The experiment has four treatments: Lovell rootstock with postplant nematicide, Lovell rootstock without postplant nematicide, Nemaguard rootstock with postplant nematicide, Nemaguard rootstock without postplant nematicide. The treatments are applied to 20-tree plots and replicated eight times through the 16-acre orchard.

During 1985, Vydate at 1 lb a.i./acre was applied to the nematicide treated rows in March, April, May, June and July. During 1986, Nemacur 3 at 5.5 lb a.i./acre was applied in April and October. In 1987, the same rate of Nemacur was applied in October. Nitrogen, in the form of UN-32, a solution of ammonium nitrate and urea, is applied through the dripper system; 10 units a.i./acre in April and September, 1985; 16 unit in April, 1986; 49 units in October, 1987; 20 units in April, 1988 and 20 units in May, 1988.

Soil samples are taken from five trees in each plot, at six week intervals for the first two years of the experiment and three-month intervals subsequently. The five trees are distributed throughout the tree row in each plot. Two cores are taken to a depth of 2 ft from each tree, providing an aggregate sample of 10 cores per plot. Nematodes are extracted from the samples using elutriation and sugar centrifugation to enhance recovery of C. xenoplax. At annual intervals, measurements of tree growth and vigor are taken, including leaf weights (five leaves from each of five trees per plot), shoot lengths, visual vigor ratings, trunk diameters, photosynthesis rates, and tree yield. Annual assessments of tree mortality and damage related to bacterial canker are also made.

RESULTS

Population densities on the untreated Nemaguard rootstock developed rapidly and approached 28,000/liter of soil by August, 1986. They remained relatively stable near that level until September, 1987. Population densities on the untreated Lovell rootstock developed at a much slower rate and reached a maximum in July, 1987. Soil in the orchard was extremely dry from September through November, 1987, preceding winter rain, and there was an application of 49 units a.i./acre of UN-32 to the whole field in October, 1987. The combination of UN-32 and dry soil apparently resulted in a decrease of population densities of C. xenoplax in all treatments at the November, 1987 sampling. Population recovery occurred in 1988, although most treatments have not reached the population levels exhibited in the summer of 1987 (Fig. 1).

The effect of fall Nemacur treatments, applied through the dripper line, has been to maintain the population at somewhat less than half of that on the untreated rows in the Nemaguard rootstock through 1987. Similar relative levels were maintained by Nemacur treatment in the plots on Lovell rootstock. Nemacur was applied in the fall of 1987, however, the population densities in the treated plots in 1988 indicate little effect of the nematicide application in either rootstock. In

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fact, there is evidence of a population explosion in the nematicide treated Nemacur plots in 1988 (Fig. 1). This may indicate the response of the nematode to enhanced food availability and confirms observations (McKenry unpublished) that Nemacur treatment is not always effective in the management of ring nematode populations in Prunus orchards.

The overall nematode stress dosage on the trees in each treatment is calculated as the cumulative product of the concentration of nematodes (population density) and the time over which that concentration is effective. This measure is calculated as cumulative nematode degree days (CNDD), the time element of the stress dosage being measured in physiological time rather than calendar time. The highest CNDD in the orchard is on the Nemaguard rootstock untreated with nematicide (over 45,000,000) (Fig. 2, Table 1). It is about one-half of this level on the untreated Lovell rootstock, reflective of the slower population build-up of the nematode. Nematicide treatment in the case of each rootstock has reduced the cumulative nematode stress dosage to about 30% of that on the respective untreated rootstock, however, this situation is changing with the apparent lack of effectiveness of the nematicide treatment in the fall of 1987 (Fig. 2).

Tree yields in August, 1988, were higher on the Lovell rootstock than on the Nemaguard rootstock, and the effect of the nematicide treatment was an approximately 8% increase in yield on each rootstock (Table 1). Total yields over a three-year period have not been affected by nematicide treatment and are very similar on both Nemaguard and Lovell rootstocks. None of the yield differences in the plots are statistically significant (Table 1). In general, plant growth measurements are greater on the Nemaguard rootstock than on the Lovell rootstock, including significant differences in root weight, leaf weight in some years, and plant vigor estimates (Table 1). The Nemacur treatment has also significantly influenced plant growth, positively in most cases (Table 1).

Tree mortality due to bacterial canker has only occurred in one part of the field, and only on Nemaguard rootstock in the presence of high population densiteis of the ring nematode. Some bacterial canker symptoms have been seen in other parts of the field, but have been limited to death of branches. In each case, the symptoms are in Nemaguard plots untreated with nematicide. No bacterial canker complex symptoms have been seen in trees on Lovell rootstock, with or without the post-plant nematicide treatment.

DISCUSSION

The nematode stress dosage model appears to provide an excellent basis for monitoring the probable impact of the ring nematode population on peach trees through time, and for economic analysis of the effects of various treatments (rootstocks and nematicides). At this time, however, there are not sufficient differences in tree growth, yield, or in the incidence of bacterial canker complex at the experimental site to allow analysis of their relationship to the nematode stress dosage.

The nematode stress dosage is very high on the Nemaguard rootstock and somewhat lower on the Lovell rootstock untreated with nematicide. In general, trees appear more vigorous on the Nemaguard rootstock, however, trees on this rootstock untreated with nematicide were the lowest yielding in 1988. Cumulative yields across three years indicate no differences among the treatments, and hence no effect of nematode stress on yield and no yield benefit from any of the treatments.

As of spring, 1988, there are three dead trees and two dead branches in the total of 160 trees of Nemaguard rootstock treated with nematicide, and two dead trees, four dead scaffolds and 93 dead branches in the 180 trees on the Nemaguard rootstock untreated with nematicide. The incidence of bacterial canker complex and its relationship with Nemaguard rootstock and high population densities of the ring nematode appears to be more economically significant in this orchard than the effect of the nematode on tree growth and yield.

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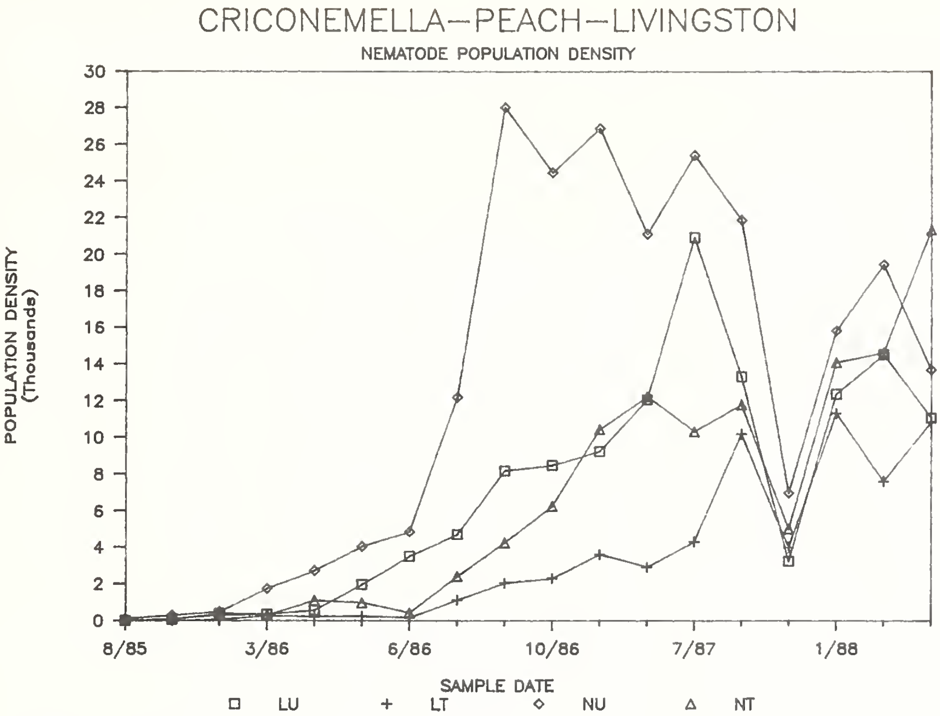

Figure 1. Criconemella xenoplax population densities per liter of soil from August, 1985 to June, 1988 on Lovell (L) and Nemaguard (N) rootstocks, treated (T) and untreated (U) with postplant nematicide. Means of 8 replications. Livingston, CA.

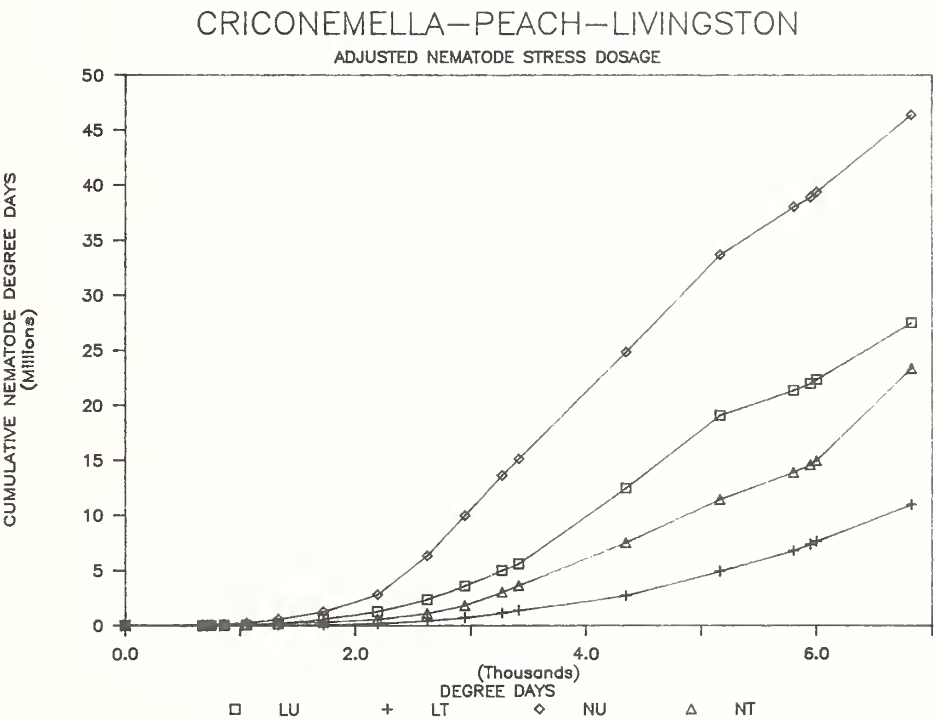

Figure 2. Cumulative nematode stress dosage from August 1985 to June, 1988 on Lovell (L) and Nemaguard (N) rootstocks, treated (T) and untreated (U) with postplant nematicide. Means of 8 replications. Livingston, CA.

Table 1.
Cumulative nematode stress dosage and plant growth data on Lovell (L) and Nemaguard (N) rootstocks, treated (T) and untreated (U) with postplant nematicides.

Criconemella - Peach - Livingston

Variable	Rootstock Means		Nematicide Means		Treatment Means			
	Lovell	Nemaguard	Check	Nemacur	LU	LT	NU	NT
CNDD6/88	20201447	34320559**	36592092	18871188**	27989406	12413488	44119441	24521676
Root Wt	16.77	23.16**	18.57	21.78**	15.84	17.70	20.96	25.35
Leaf Wt86	5.98	6.31	6.61	5.70**	6.39	5.57	6.80	5.81
Leaf Wt87	5.86	6.34**	6.18	6.05	5.85	5.88	6.47	6.21
Leaf Wt88	6.61	6.54	6.52	6.62	6.36	6.85	6.66	6.42**
Tot Leaf Wt	18.45	19.19**	19.31	18.38**	18.60	18.30	19.94	18.45*
Shoot Lnth86	94.31	93.05	93.24	94.04	93.51	95.12	93.01	93.09
Shoot Lnth87	56.05	57.43	54.73	58.83*	52.48	59.61	56.71	58.15
Shoot Lnth88	67.30	64.02	64.80	66.29	67.17	67.41	62.73	65.31
Tot Shoot Lnth	217.65	214.50	212.77	219.17	213.16	222.15	212.44	216.56
Vig86	2.43	2.68*	2.48	2.64	2.26	2.60	2.68	2.68
Vig87	2.84	2.91	2.85	2.91	2.80	2.89	2.89	2.93
Vig88	2.79	2.92*	2.79	2.93*	2.69	2.89	2.88	2.96
Tot Vit	8.06	8.50**	8.11	8.47**	7.74	8.37	8.44	8.56
Yld86	5.23	4.96	5.68	4.49	5.93	4.52	5.47	4.46
Yld87	122.63	133.12	133.14	123.30	126.12	119.14	139.29	126.95
Yld88	127.24	118.25	117.97	126.91	122.82	131.66	113.74	122.76
Tot Yld	255.09	256.33	256.80	254.71	254.87	255.32	258.49	254.18
Photo86	12.33	13.10	12.50	12.99	12.24	12.43	12.73	13.48
Photo87	11.47	10.17	10.53	11.02	11.06	11.89	10.08	10.26

Fungi Session

PEACH TREE FUNGAL GUMMOSIS

Floyd F. Hendrix and Kerry O. Britton

ABSTRACT

Fungal gummosis of peach trees is caused by Botryosphaeria dothidea, B. rhodina and B. obtusa. A two year isolation study showed that at least one of these species inhabit cankers most of the year. In the summer and early fall, B. rhodina, present at low levels, occurs mostly in the late summer. Wounds are the most important infection court for all three species. However, B. obtusa can infect trees through buds, and B. dothidea can infect through lenticels. After infection, all species move systemically in the tree. Symptom development is slow, and mycelium extends as much as 15 cm beyond the visible canker.

Gum ratings were inconsistent with vascular discoloration or rate of fungal colonization for comparison of disease severity on different cultivars. In a greenhouse study of cv Blake, there were significant correlations between amount of gum, vascular discoloration, fungus colonization, and external necrosis. These variables did not correlate with subsequent tree growth.

Peach tree fungal gummosis (PTFG) was observed in central Georgia in the late 1960's, and Botryosphaeria dothidea was identified as a causal agent in 1974 (9). Symptoms include copious gum exudation, sunken lesions around lenticels, blisters beneath lenticels and necrotic lesions in the bark. Larger cankers have cracked, flaking bark, and usually are centered around pruning wounds. These cankers slowly enlarge, girdling small limbs.

In 1982, B. obtusa and B. rhodina were shown to cause symptoms indistinguishable from those caused by B. dothidea (1). In other crops, these fungi are reported to enter through wounds, buds, lenticels and growth cracks (3). Botryosphaeria spp. are also secondary invaders and saprophytes, and sporulate profusely on bark of dead wood on the ground or in the tree. They are most aggressive on stressed plants (4).

Reilly and Okie (6) demonstrated that pruning wounds created in March were susceptible for four weeks while those made in August were susceptible for only two weeks. Weaver (9) found that susceptibility varied with season and length of incubation period. Comparing isolates from peach and other crops, Pusey et al. (5) found that disease severity, judged by gum production, reversed as incubation periods were extended.

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METHODS AND RESULTS

Field Surveys

Peach twigs naturally infected with PTFG from four orchards in central Georgia were sampled at monthly intervals for 2 yr. Twigs were cut into 2.5 cm lengths, starting at the center of the canker, and extending into symptomless tissue. They were surface-sterilized in 0.5% sodium hypochlorite in 10% ethanol and placed on acidified potato dextrose agar (APDA). Botryosphaeria spp. from each segment were recorded. Samples from twigs, scaffold limb and trunk cankers were also surveyed to determine if any difference in species composition existed.

Botryosphaeria species were isolated 11 times more frequently from twigs than from scaffold limbs or trunks. However, there was no difference in species composition.

From twig isolations it was determined that significant seasonal shifts in species composition occurred. B. dothidea was the dominant species in the summer but was not isoalted in the winter. B. rhodina was isolated in the early summer and in the fall. B. obtusa was dominant in the late fall, winter and early spring, representing more than 50% of the Botryosphaeria present October-May, but less than 10% in the summer and early fall. B. obtusa was isolated from the canker margins most frequently in the fall, winter and spring, while B. dothidea was most frequent in the summer.

Cultivar Comparisons

Daniell and Chandler (2) rated 27 naturally infected cultivars, judged by gum production, for susceptibility to PTFG. Harbrite was deemed highly resistant, followed by Harken, Pekin, Harmony, and White English. Winblo was the most susceptible. We wound inoculated Harbrite, Harken and Winblo using all three Botryosphaeria spp. After 8 months, twigs were removed from the trees, cut into 2.5 cm sections and plated out. Length of vascular discoloration was recorded. Gum exudation was also rated.

No significant difference due to fungal species was found. Harbrite and Harken produced less gum and had less extensive vascular discoloration than Winblo. However, there was no difference in fungal colonization in the three cultivars.

In 1983, cv Summergold, Loring, PI 101686, PI 43289 and Harbrite were inoculated with all three Botryosphaeria spp. Due to poor reisolation of B. dothidea, the experiment was repeated in 1984 using only that species, and substituting 'Redglobe' for 'Summergold' due to short supply of that cultivar. B. rhodina stimulated more gum production than the other two species. The cultivar rating for gum production was similar for all three species. 'Summergold' and 'Loring' produced more gum than the other cultivars. 'Harbrite' was most successfully colonized by B. obtusa. PI 43289 and PI 101686 were next in the rank order for B. obtusa and B. rhodina. No difference in invasion rate or vascular discoloration was observed among the cultivars for B. dothidea.

Fungal Species Aggressiveness

'Blake' trees in the greenhouse were inoculated with all three species to compare pathogen species' aggressiveness. The weight of gum produced was correlated with the extent of necrosis, vascular discoloration and fungal invasion. All of those factors were more severe on trees inoculated with B. rhodina. Growth before inoculation was the only factor correlated with tree growth after inoculation.

Bud Infection Surveys

In Georgia, B. obtusa infects apples through opening buds at the silver tip stage of bud phenology (7). Field surveys, inoculations and histological studies were made to determine if similar infections occur on peaches.

Starting in August, 50 symptomless buds were taken biweekly from trees in four orchards near Ft. Valley, Georgia. Half were surface sterilized, and all planted on APDA. Sampling continued until the following March. Bud infestation with B. obtusa occurred at low levels until January when it increased to 44% on non-sterilized buds and 32% on sterilized buds. B. dothidea and B. rhodina were not present in buds.

After bloom, isolations from nodes under developing fruit showed 23% of the twigs were infected. Twigs produced in spring 1982 were 25% infected by spring 1983, and 40% infected by spring 1984. Twigs produced in spring 1983 were infected at the same rate. However, twigs produced in 1984 became 15% infected that fall, rather than the following spring. We believe these infections to be the result of systemic mycelial growth, rather than bud infections.

Bud Inoculation

Potted trees of cv Loring, kept outdoors, were inoculated with conidia of all three species of Botryosphaeria in October 1981. Both B. obtusa and B. rhodina significantly increased bud mortality (20.5 and 32.6%, respectively). B. dothidea did not increase bud mortality significantly over the check.

Fungicide Tests

Captafol applications (2.14 l/ha) were applied in 1983 and 1984 to a 10-yr-old orchard at Ft. Valley, Georgia, starting January 23, with four additional plots sprayed each week for a total of four intervals. Individual plots received only one spray application. None of the sprays significantly reduced twig infection. Further isolations showed that 25% of the twigs bearing the buds were infected due to systemic movement of the fungus.

This test was moved to a newly planted orchard in 1984, and this orchard was sprayed yearly in January from 1984-87. In 1986, 54% of the non-sterilized buds yielded B. obtusa. Fungicide applications reduced bud and subtending twig infection by 50%. In 1987, bud infection was reduced 50%, but there was no reduction in subtending twig infection. This was probably due to systemic movement of the fungus from 1986 infections.

Histology

Histological studies of buds revealed many conidia lodged in crevices between bud scales, sepals and petals in December and January. In mid-February germination of spores and penetration of petal parenchyma and sepals occurred. Hyphae invaded cortical tissue beneath the bud intercellularly. Gum ducts formed in concentric areas in the adjacent xylem. Hyphae grew along ray parenchyma into the xylem. In late stages of infection, large vessel elements contained hyphae.

DISCUSSION

The onset of PTFG as an epidemic coincided with changes in cultural practices associated with the control of peach tree shortlife. Discontinuing discing left much pruning wood on the surface of the ground. Mowing prunings does not destroy them to a point that prevents infestation and sporulation by Botryosphaeria spp. (8). The resulting explosion in availability of inoculum may have been enough to increase this disease from a mycological curiosity to epidemic proportions.

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WOOD DECAY FUNGI AND THEIR ROLE IN THE DECLINE OF FRUIT AND NUT TREES IN CALIFORNIA

J.E. Adaskaveg and J.M. Ogawa

ABSTRACT

In the fall and winter seasons of 1986-87 and 1987-88, surveys in commercial fruit and nut orchards were conducted in ten counties throughout the Sacramento and San Joaquin Valleys of California. Orchards assessed for wood decay were generally $\geq$ 15 yr old and included: almond, peach and nectarine, apricot, plum and prune, fig, and walnut. Fungal species collected as fruiting bodies and their incidence differed between crops and orchards surveyed. Fruiting bodies of wood decay fungi were also collected from the hosts previously mentioned as well as from cherry, pistachio, and olive, in orchards not surveyed for wood decay. Thirty-three species of fungi were collected from 23 genera. The majority of the fungi collected caused or were associated with white wood rots; whereas three genera caused brown wood rots; and the decay of one genus was undetermined. Wood decay and fruiting bodies were primarily associated with wounds on trunks and scaffold branches. Trees with wood decay were commonly associated with orchards showing a decline in shoot growth, limb breakage, and decayed root systems. Several species collected in this survey have been implicated as pathogens of various fruit tree species by other researchers.

Wood decay disorders occur in commercial fruit and nut trees throughout California. The fungi causing these disorders are primarily in the Basidiomycotina. Information available on these fungi in fruit orchards is limited to mycological descriptions (9,10,18) and scattered reports of incidence on various hosts (1,8,22). Detailed surveys of wood decay fungi on apple trees have been conducted in Washington (5,11) and Minnesota (2,7). To date no specific studies or surveys of wood decay fungi have been published on stone fruit trees in California.

The purpose of this study was to determine: 1) species of wood decay fungi found on selected stone fruit trees; 2) incidence of these species and wood decay in surveyed orchards; and 3) association of tree wounds and decay fungi on surveyed trees.

MATERIALS AND METHODS

Twenty-nine, 15-yr old orchards in California under Commercial production were selected in 10 counties in both the San Joaquin and Sacramento Valleys. Numbers of trees, orchards surveyed, and crop varieties were (crop/no. of orchards/total trees/ varieties): almond/15/2688/Carmel, Drake, Merced, Mission, NePlus Ultra, Nonpareil, and Thompson; apricot/2/210/Blenheim, and Perfection; fig/2/50/Calimyrna; nectarine and peach/4/408/Flamekist (nectarine), Loadel, Starn, and Fay Elberta; plum and prune/3/300/Friar and French, respectively; and walnut/3/133/English on native Black. Fruiting bodies, type of decay, and wounds associated with specific tree portions were determined for each tree surveyed.

Fruiting bodies of wood decay fungi were also collected from the hosts previously mentioned as well as from cherry, pistachio, and olive, in orchards not surveyed for wood decay. Fruiting bodies collected were identified using macro- and microscopic characteristics (9,10,12). Fungi were cultured on 2% malt extract agar and identified (16,17,23).

RESULTS AND DISCUSSION

Wood decay within the orchards ranged from 21-92% with almond having 25%, peach and nectarine 36%, apricot 21%, plum and prune 36%, fig 92%, and walnut 34% decay. Table 1 indicates the incidence of decay fungi collected as fruiting bodies from each crop surveyed. Predominate fungal genera found on Prunus sp. were Oxyporus, Ganoderma, Laetiporus, Trametes, Fomitopsis, Armillaria, Phellinus, and Perenniporia. Common genera on walnut were Armillaria and Pleurotus, while on fig only species in the genus Inonotus were found.

Thirty-three species of fungi were collected from the following genera: Armillaria, Ceriporia, Coprinus, Fomitopsis, Ganoderma, Hypoderma, Hyphodontia, Inonotus, Laetiporus, Lenzites, Oxyporus, Peniophora, Perenniporia, Phanerochaete, Phlebia, Phellinus, Pholiota, Pleurotus, Schizophyllum, Schizopora, Sistotrema, Stereum, and Trametes. Three genera, Coprinus, Fomitopsis, and Laetiporus, caused brown wood rots, decay by the Pholiota species was undetermined, while the remaining genera were associated with or caused white wood rots. Species collected or reported in California on stone fruit trees are presented in Table 2.

Basidiocarps and decayed wood were commonly associated with tree wounds created by: mechanical harvesters, canopy support methods, pruning,and sunburn. Limb breakage during fruit production and uprooted trees during wind storms were damages primarily associated with wood decay in scaffold branches and roots of infected trees, respectively. In some cases, wood decay of specific portions of infected trees was limited to certain genera of fungi. For example, species of Perenniporia, Schizophyllum, Stereum, and Trametes, were commonly found on scaffold branches associated with pruning and sunburned wounds. Species in the genera Armillaria, Ganoderma, and Oxyporus were primarily collected from roots and lower portions of trees in association with trunk injuries. Other fungi, such as those in the genera Laetiporus and Phellinus, caused decay in roots, trunks, and scaffold branches of trees.

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Two of eight most common fungal genera, Laetiporus and Fomitopsis, collected in surveyed orchards caused brown wood rots. Generally, fungi that cause brown wood rots cause a greater reduction in wood strength and weight loss than fungi that cause white wood rots in the same time period. The high incidence and destructive nature of species in these two genera suggests that these species may play a major role in the decline of fruit and nut trees in California.

The majority of fungi collected caused white wood rots. The role of these fungi in the decline of fruit and nut trees is not well established, except for species of Armillaria which are known root rot pathogens of fruit trees (19,20,24) and Chondrostereum purpureum, the causal organism of silver leaf disease of fruit trees (21). The other genera of fungi in high incidence in surveyed orchards that may contribute to declining orchards are Ganoderma, Trametes, and Oxyporus. Bergdahl and French (2) indicated that Oxyporus latemarginatus (= Irpex tulipiferae), Trametes versicolor (= Coriolus versicolor), and Schizophyllum commune could cause decline of 3 yr old apple trees in less than optimal growing sites in Minnesota. Pathogenicity of Trametes versicolor on young apple trees (2-3 leaf stage) in Washington has also been reported (3). Dilley and Covey (5) further associated dieback symptoms with T. versicolor on mature apple trees in Washington, while in Australia this fungus is also known to cause a serious disease of mature apple trees (4,13,14,15). The significance of wood decay fungi in California needs to be further evaluated and management strategies designed to limit their introduction and spread in newly established (2-3 years) and older commercial orchards.

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Table 1.
Predominant fungal genera and their incidence in fruit and nut tree orchards in California[1].

Orchards Surveyed[2]					
Almond	Apricot	Fig	Peach and Nectarine	Plum and Prune	Walnut
Armillaria (0.8%)	Laetiporus (4.3%)	Inonotus (18.3%)	Armillaria (0.8%)	Fomitopsis (4.3%)	Armillaria (1.5%)
Ganoderma (3.1%)	Oxyporus (5.7%)		Ceriporia (0.2%)	Oxyporus (0.7%)	Laetiporus (0.7%)
Laetiporus (1.6%)	Phellinus (0.9%)		Ganoderma (24.3%)	Perenniporia (0.7%)	Pleurotus (3.0%)
Oxyporus (4.0%)	Perenniporia (1.0%)		Oxyporus (0.7%)	Phellinus (2.7%)	
Perenniporia (0.6%)	Trametes (6.7%)		Phellinus (1.2%)	Stereum (1.0%)	
Phellinus (1.0%)			Pholiota (0.2%)	Trametes (0.3%)	
Stereum (0.4%)			Schizophyllum (0.9%)		
Trametes (1.6%)			Trametes (1.7%)		

[1]Predominant fungal genera collected as basidiocarps on living trees in commercial production and their incidence based on total trees surveyed for each crop.

[2]Orchards surveyed: almond (Carmel, Drake, Merced, Mission, NePlus Ultra, Nonpareil, and Thompson); apricot (Blenheim and Perfection); fig (Calimyrna); nectarine (Flamekist); peach (Loadel, Starn, and Fay Elberta); plum (Friar); prune (French); and walnut (English grafted on California Black).

Table 2.
Common wood decay fungi of selected fruit and nut tree species in California.

Fungus	Host[a]	HA[b]	Decay[c]	Source[d]
Abortiporus biennis (Bull.:Fr.) Sing.	2,3	1,2	W	L
Armillaria spp.	1-10	1,(2)	W	L
Armillaria mellea Fr.	5,9	1,(2)	W	A
Ceriporia spissa (Schw.:Fr.) Rajch.	9	2	W	A
Chondrostereum purpureum (Pers.:Fr.) Pouz.	6,8,9	1,2	W	L
Coprinus spp.	11	1,2	B	A
Daedalea quercina Fr.	2	(1),2	B	L
Daedaleopsis confragosa (Bolt.:Fr.) Schroet.	2	(1),2	W	L
Fomitopsis cajanderi (Karst.) Kotl. et Pouz.	8	(1),2	B	A
Ganoderma annularis (Fr.) Gilbn.	5,9	1,(2)	W	A
G. applanatum (Pers.) Pat.	9	1,(2)	W	A
G. brownii (Murr.) Gilbn.	5,9	1,2	W	A
G. lucidum (W. Curt.:Fr.) Karst.	5,7,9,11	1,2	W	A
Hyphoderma puberum (Fr.) Wallr.	5	2	W	A
Hyphodontia aspera (Fr.) J. Erikss.	5	2	W	A
Inonotus cuticularis (Bull.:Fr.) Karst.	1	1	W	A
I. rickii (Pat.) Reid	1	1	W	A
Irpex lacteus (Fr.:Fr.) Fr.	7,11	(1),2	W	L
Laetiporus sulphureus (Bull.:Fr.) Murr.	2,5,11	1,(2)	B	A
Lenzites betulina (Fr.) Fr.	5,7	(1),2	W	A
Oxyporus corticola (Fr.) Ryv.	9,11	2	W	A

Table 2--Continued
Common wood decay fungi of selected fruit and nut tree species in California.

Fungus	Host[a]	HA[b]	Decay[c]	Source[d]
O. latemarginatus (Dur. & Mont. ex. Mont.) Donk	7	1,2	W	A
O. similis (Bres.) Ryv.	5,9	1,2	W	A
Peniophora albobadia (Schw.:Fr.) Boidin	5	2	W	A
Perenniporia medulla-panis (Jacq.:Fr.) Donk	11	1	W	A
Phanerochaete velutina (Fr.) Karst.	9	2	W	A
Phlebia rufa (Fr.) M.P. Christ.	5	2	W	A
Phellinus ferruginosus (Schard.:Fr.) Bourd. et Galz.	11	(1),2	W	L
P. gilvus (Schw.) Pat.	5,9,11	1,2	W	A
P. igniarius (L.:Fr.) Quel.	11	1	W	L
P. pomaceus (Pers.:S.F. Gray) Maire	5	2	W	A
P. robustus (Karst.) Bourd. & Galz.	5,8	1	W	A
P. texanus (Murr.) A. Ames	8	1	W	A
Pholiota sp.	11	1	NS	A
Pleurotus ostreatus (Fr.) Kummer	2,4	1,2	W	A
Pycnoporus cinnabarinus (Jacq.:Fr.) Karst.	11	2	W	L
Schizophyllum commune Fr.	1,2,4-7	1,2	W	A
Schizopora flavipora (Cke.) Ryv.	5	2	W	A
Sistotrema brinkmannii (Bres.) J. Erikss.	9	2	W	A
Stereum hirsutum (Willd.:Fr.) S.F. Gray	5,8,9	1,2	W	A

Table 2--Continued
Common wood decay fungi of selected fruit and nut tree species in California.

Fungus	Host[a]	HA[b]	Decay[c]	Source[d]
Trametes hirsuta (Wulf.:Fr.) Pilat	6,9,11	1,2	W	A
T. versicolor (L.:Fr.) Pilat	3,5-9	1,2	W	A

[a]Hosts included: (1) Ficus carica L. (Fig); (2) Juglans spp. (Walnut); (3) Olea spp. (Olive); (4) Pistacia vera L. (Pistachio); (5) Prunus dulcis (Mill.) W.A. Webb (Almond); (6) P. armeniaca L. (Apricot); (7) P. avium L. (Cherry); (8) P. domestica L. and P. americana L. (Prune, Plum); (9) P. persica (L.) Batsch. (Peach); (10) P. salicina Lindl. (Japanese Plum); and (11) Prunus species. Host numbers separated by semicolons correspond to occurrence by state.

[b]Host association (HA): 1 - Living trees; (1) - Possibly living trees; 2 - Dead wood; (2) Possibly dead wood; 3 - Not specified.

[c]Wood Decay: W = White wood rot; B = Brown wood rot; NS = Not specified.

[d]Information obtained from author (A) or from literature (L) listed in reference section of this paper.

STONE FRUIT DECLINE: ROOTSTOCK INFLUENCE ON COLD HARDINESS OF PEACH, AND FLOODING TOLERANCE OF CHERRY

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ABSTRACT

The influence of rootstock on acclimation and cold hardiness of peach was investigated over a two-year period. H7338001, Boone County, Tennessee Natural and Halford were medium-high rated to cold resistance. In 1986/87, winter survival of Redhaven on Halford (92%) and Redhaven on H7338001 (83%). Redhaven own-rooted and on Nemaguard showed minimum survival and maximum tenderness in the period tested. Relative tolerance of various cherry rootstocks to waterlogging was determined for potted one-year-old plants. Rootstocks tested include Mahaleb, Mazzard, Montmorency, Colt, MxM clones 2, 39 and 60, and Gissen clones 148/1, 148/9, 195/1, 192/2 and 196/4. As a group, tested rootstocks displayed a smaller range of tolerance and a more rapid onset of injury than has been reported for rootstocks of other temperate deciduous tree fruit species, e.g., apples and pears.

INTRODUCTION

The stone fruit decline project in Michigan covers four crops (peach, sour cherry, sweet cherry, and plum), with research conducted by 11 different scientists and their students and technicians, in four different departments (Botany and Plant Pathology, Agricultural Engineering, Horticulture, and Entomology). In our program we have concentrated on cold acclimation and hardiness in peach, accelerated production of peach, trunk and leaf damage thresholds in cherry, and flooding tolerance of cherry. In this paper we report on only two aspects of that program, the rootstock influence on hardiness of peach, and the rootstock influence on flooding tolerance of cherry.

There are not many studies on the influence of rootstock on cold hardiness of peach shoots. The few existing in the literature have focused mainly on comparisons of common rootstocks with ones especially selected for cold hardiness (3,5,6,8). The purpose of this study was to determine the cold hardiness of rootstocks which seem adapted particulary well to the Northern United States and Canada.

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Decline of sour cherry has been attributed to a number of biotic (root rots, insects, diseases, nematodes) and abiotic (soil drainage, winter damage, mechanical harvesting damage) factors. However, in Michigan we have generally observed affected trees in conjunction with locally restrictive soils, i.e., heavy subsoils, plow pan, etc., that are prone to root zone flooding when subjected to heavy rainfall and/or irrigation (Perry, 1982). The two most common cherry rootstocks, seedlings of Prunus mahaleb L. and P. avium L. (Mazzard), were found by Saunier (9) and Beckman (1) to be extremely sensitive to waterlogging. Recently a number of relatively new rootstocks have been subjected to limited commercial trials. Neither these nor new advanced releases from breeding programs have generally been evaluated for tolerance to waterlogging. Herein we report on relative tolerance to waterlogging of selected rootstocks when grown in 5 liter pots.

MATERIALS AND METHODS

Hardiness of Peach

Redhaven peach trees grafted to rootstocks listed in Table 1 were planted in 1982 on a Kalamazoo sandy loam of alluvial origin at the Horticultural Research Station at Michigan State University, Clarksville, MI (43 N latitude, 995 feet altitude). Siberian C and GF 655-2 were planted at the same location in 1983. Trees were spaced 20 x 20 feet and trained to an open center. Treatments were different rootstocks, completely randomized on 4 experimental units, each unit consisting of 3 trees. Trunk diameters to indicate vigor were measured annually at 30 cm from the ground and cross-sectional areas calculated. One-year-old shoots were collected from well-exposed parts of the canopy. Freezing tests and injury evaluations of peach shoots were performed as described in Gucci and Flore (1988). T_{50} values indicate the temperature (in C) at which 50% of the tissue was killed in an artificial freezing test. Five dates of sampling were chosen in 1986/87, seven in 1987/88.

Relative water content of shoots was determined from fresh and dry weights, the latter measured after freeze-drying the tissue to constant weight. Percentage of tree survival was calculated based on a two-value scale (0 = dead; 1 = alive).

Cherry Tolerance to Waterlogging

Ninety-six cherry trees (8 each of Montmorency on 12 different rootstocks, Table 2) were cut back to a single unbranched stem ca. 50 cm tall and planted in 7 liter plastic containers filled with a sterilized soil mix (ca. 50% sandy loam, 30% sphagnum peat and 20% sand v/v). Plants were grown in an unshaded greenhouse at the Pesticide Research Center, MSU. Water, pesticides and nutrients were added as needed. Four weeks after planting, half of the trees of each rootstock combination were flooded by placing each tree container in an 11 liter container lined with a plastic bag filled with tap water adequate to cover the soil.

Table 1.
Origin, vigor, and other relevant characteristics of peach rootstock tested as reported from the literature and personal observations.

Rootstock	Origin	Scion Vigor	Other
Redhaven	P. persica	*	*
Halford	P. persica	high	standard seedling stock
Nemaguard	P. persica x	high	nematode resistant
H7338001	Bailey x Siberian C	?	nematode and cold resistant
Boone Co.	P. persica	high	lesion nematode and cold resistant
Tennessee Natural	P. persica	high	cold resistant
Siberian C.	P. persica	medium/ low	cold resistant
GF 655-2	P. insititia	medium/ low	high fruit quality

*Redhaven is usually used as a standard for comparisons. Sources of plant material: Redhaven, Michigan State University, MI, USA; Halford, Boone County, Tennessee Natural: IR-2, USDA, Prosser, WA, USA; Nemaguard: Dave Wilson Nursery, Hughson, CA, USA; H7338001: Harrow Research Station, Harrow, Ontario, Canada; Siberian C, GF 655-2: Hilltop Trees, Inc., Hartford, MI, USA.

Flooding was releived 5 days later by allowing pots to gravity drain, with the remaining water removed via a vacuum pump. During the 5 day flooding treatment, all control plants were watered to saturation as needed, as were all treatments during a 10 day recovery period. The following parameters were monitored: gas exchange (photosynthesis, transpiration, and stomatal conductance), shoot length and leaf area (see Beckman (1) for experimental details). At the termination of the recovery period, plants were partitioned into root system, trunk, new shoots and leaves and oven dried for at least 1 week at 90°C.

RESULTS AND DISCUSSION

Peach Hardiness

Because of the different date of planting, comparisons of Redhaven on different rootstocks were divided into two groups; one including Siberian C and GF 655-2, and the other including

Table 2.
Sour cherry rootstocks[z] utilized in study.

Seedling Stocks	Virus Free Status
Prunus mahaleb (Mahaleb)	presumed
P. avium (Mazzard)	presumed
Clonal Stocks	
P. cerasus (Montmorency	certified
P. avium x pseudocerasus (Colt)	certified
P. avium x mahaleb (MxM 2, 39 and 60)[y]	presumed
P. cerasus x canescens (148/1 & 148/9)[x]	certified
P. canescens x cerasus (195/1 & 195/2)[x]	certified
P. canescens x avium (196/4)[x]	certified

[z]Supplied by Hilltop Corp., Hartford, MI. All grafted with P. cerasus cv. Montmorency except own-rooted Montmorency.

[y]Presumed natural hybrids.

[x]Advanced selections from Giessen, W. Germany Breeding Program.

the remaining six. In the latter group no significant differences (P = 0.05) in scion vigor, as assessed by trunk cross-sectional area, were found between the rootstocks (Figure 1). Exceptions were Redhaven on Nemaguard, the most vigorous in both 1984 and 1987, and H7338001, the least vigorous in 1987. When considering the increments in trunk girth between 1984 and 1987, there existed no differences among the six. Redhaven on Siberian C was more vigorous than GF 655-2 in 1984-87 (Figure 1a). This confirms earlier reports that indicated that Nemaguard was a vigorous rootstock, and that Siberian C was more vigorous than GF 655-2 (Layne, 1987). Redhaven on Nemaguard also resulted the most productive over the 1985-87 period, while Redhaven own-rooted and Redhaven on Halford were the least productive (Figure 1b). Redhaven on Siberian C was more productive than on GF 655-2 (Figure 1b). High yields may have been the result of rapid growth in the early years after planting that allowed the tree to achieve a sizeable fruit-bearing capacity earlier, as it can be seen from the positive association between trunk growth and yields. However, these observation are preliminary, and the evaluation of potential for high yields can be better estimated after a period longer than that spanned in this study. The influence of rootstocks on cold hardiness of Redhaven for 1986/87 and 1987/88 (data until February for 1987/88) is reported in Tables 3 and 4. Stages of acclimation and deacclimation have been estimated from weekly T_{50} data (G.S. Howell, Jr., personal communication). In 1986, acclimation was considered ended by the 2nd week of December, in 1987 by the 1st 1986/87, Redhaven own-rooted was less hardy than the other rootstocks during

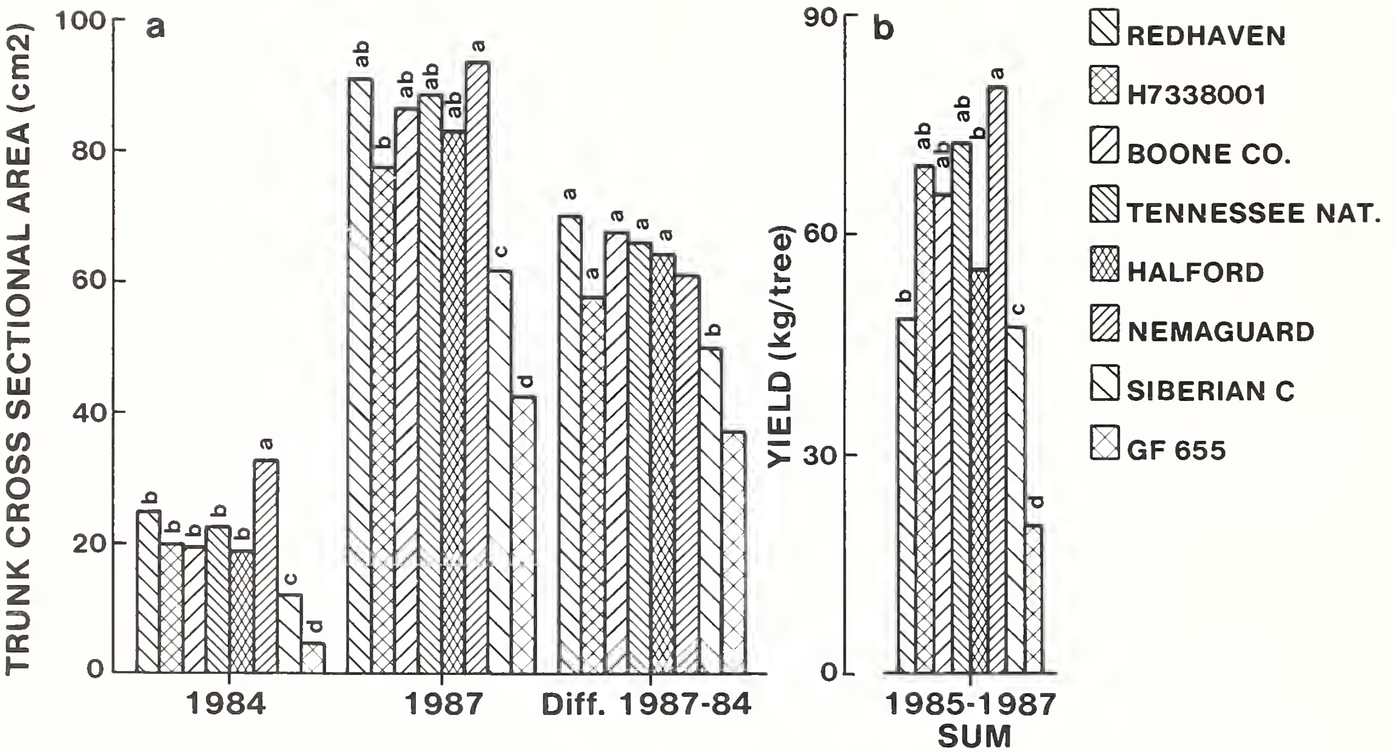

Figure 1. (a) Trunk cross sectional areas and relative increments over the period 1984/87. Different letters indicate statistical significance at the 5% level. Siberian C and GF 655-2 compared separately from the other 6 rootstocks because of their younger age.

Figure 1. (b) Yeilds of 'Redhaven' over 8 different rootstocks cumulated over the period 1985/87. Different letters indicate statistical significance at the 5% level. Siberian C. and GF 655-2 compared separately for reason explained in (a).

acclimation. Differences of T_{50} were larger in 1986/87 than in 1987/88. In the same period of 1987/88, no significant differences were found among rootstocks (Table 4). Two factors may have contributed to this different behavior: variability of temperatures between the two seasons and the lowest survival shown by the above mentioned rootstocks at the end of winter 1987 (Table 3). This latter event caused the death of the most sensitive trees; trees that were dead by the end of winter 1987 were eliminated from 1987/88 sampling. Mid-winter hardiness was lowest for Redhaven on its own roots in 1986/87, but no differences were found among the other five rootstocks. In 1987/88 no differences emerged during this period. Similarly no differences were found in April 1987. However, when the small non-significant differences of T_{50} present at each date are summed over the entire period of winter rest, Redhaven own-rooted and Nemaguard revealed higher cold susceptibility, in accord with what was reported in previous studies (5). The remaining four rootstocks performed similarly even when considering cumulated T_{50} (Table 3). Siberian C appeared slightly less hardy or of equal hardiness than GF 633-2 during acclimation in both years. In November 1986 and April 1987, Siberian C proved hardier than GF 655-2. Differences were seldom significant (P = 0.05) and sums over the whole period showed no difference in 1986/87, but GF 655-2 hardier in 1987/88. The concept of considering the cold hardiness of a rootstock or variety over the whole period of rest is very important. Differences between rootstocks are often small and statistically not significant at each sampling date, but if they are consistent over several days, they may indicate relevant differences in potential for hardiness.

A number of indices or symptoms based on observations alone are commonly used to estimate cold hardiness of fruit trees empirically. Early leaf abscission by a cultivar is often considered indicative of early acclimation, and thereafter, of greater resistance to low temperatures. In a previous paper, we pointed out the lack of correlation between time of leaf abscission and cold hardiness of peach shoots (2), and the risk involved in relying on such observations. Another index used to estimate cold hardiness of woody plants is the relative water content of the tissue. Relative water content of peach shoots decreases during acclimation, reaches a minimum in winter, and then gradually increases as the vegetative activity of the tree starts again in spring (Figure 2). Changes in relative moisture content of shoots are positively correlated with susceptibility to low temperatures from fall to spring (4 = 0.79), but not when the comparison is made within each date. Therefore, although loss of water is one

Table 3.
Temperature at which 50% of the tissue was killed (T_{50}) as assessed by freezing tests in the lab and evaluation of browning of one-year-old shoots of peach 'Redhaven' on eight different rootstocks.

Rootstock	Acclimation		Mid-winter (DATE)		Deac-climation	Sum	Tree Mortality %
1986/87	10/21/86	11/18/86	2/8/87	3/19/87	4/29/87	T_{50} /day	
Redhaven	-13.5a	-17.5	-21.3b	-21.9	-6.2	-16.1	17
Halford	-15.8bc	-19.2	-25.3a	-23.3	-6.7	-18.1	8
Nemaguard	-14.6ab	-19.2	-24.4a	-23.8	-5.8	-17.6	8
H7338001	-14.8abc	-18.8	-24.0a	-24.6	-6.2	-17.7	17
Boone Co.	-15.5abc	-18.5	-24.9a	-23.7	-5.8	-17.9	0
Tennessee Natural	-13.2a	-19.2	-25.8a	-25.4	-5.8	-17.9	0
Siberian C*	-17.1	-20.4	-24.9	-23.7	-6.2	-18.5	0
GF 655-2*	-18.2	-18.2	-25.8	-25.0	-4.4	-18.3	0

Means are separated by each date by Duncan's multiple range test (P = 0.05).

*Siberian C and GF 655 were compared separately from the other 6 rootstocks because of their later date of planting.

Tree mortality was assessed at the end of winter 1987.

Table 4.
Temperature at which 50% of the tissue was killed (T_{50}) as assessed by freezing tests in the lab and evaluation of browning of one-year-old shoots of peach 'Redhaven' on eight different rootstocks, 1987/88.

Rootstock	Acclimation (DATE)				Mid-Winter			Sum
1987/88	9/16/87	10/6/87	10/19/87	11/19/87	12/22/87	1/25/88	2/18/88	T_{50} /day
Redhaven	-5.8	-11.7	-15.8	-19.3	-23.8	-25.0	-23.1abc	-18.0
Halford	-6.8	-11.5	-14.8	-18.2	-24.9	-25.5	-21.8c	-17.6
Nemaguard	-6.8	-11.8	-15.5	-17.3	-24.0	-25.9	-23.7ab	-17.9
H733800a	-6.5	-12.0	-16.0	-18.9	-24.4	-25.9	-24.3a	-18.3
Boone Co.	-6.7	-11.0	-15.7	-18.2	-24.0	-26.1	-22.4bc	-17.5
Tennessee Natural	-7.0	-11.0	-15.8	-17.3	-23.8	-25.2	-23.9bc	-17.7
Siberian C	-6.3	-11.0	-15.0	-19.1	-22.7	-24.3	-23.3b	-17.4
GF 655-2	-6.3	-11.3	-15.2	-19.1	-23.8	-24.1	-25.8a	-18.0

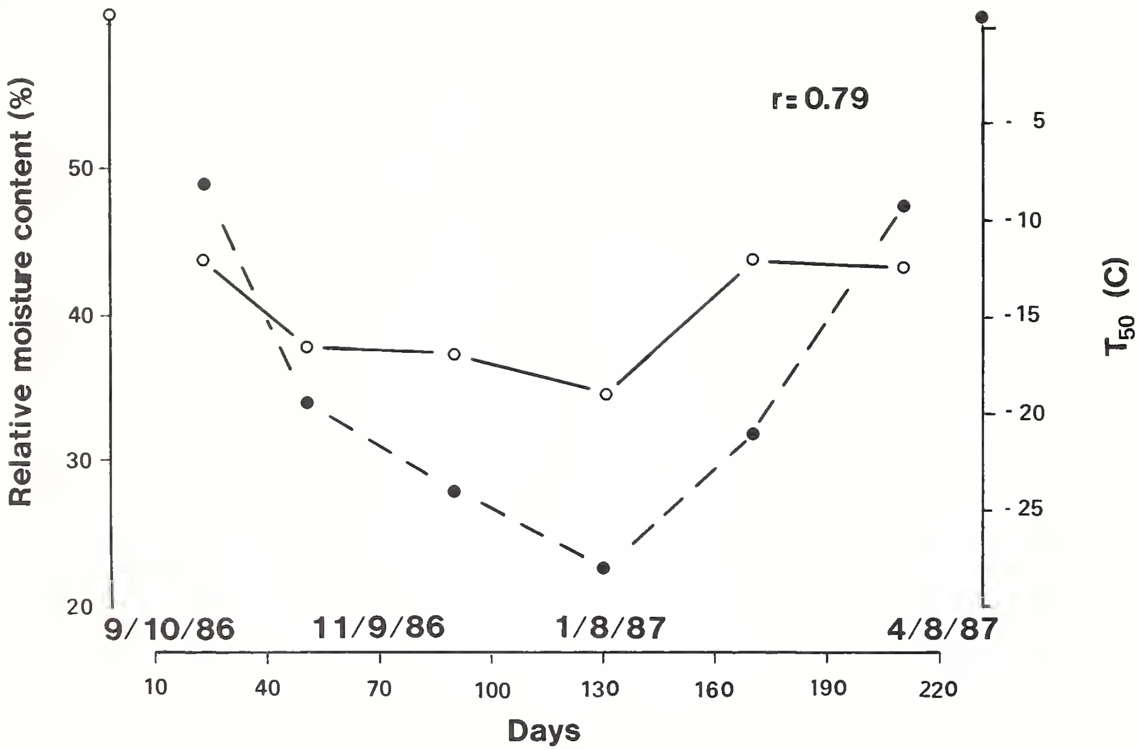

Figure 2. Changes of cold hardiness (T_{50}) and relative moisture content (%) of 'Redhaven' peach shoots during winter of 1986-87.

aspect of the hardening process undergone by the tissue in fall, by no means can relative water content be used to predict cold resistance. As it can be seen from Table 5, at each single date of 1986/87 differences in relative water content between rootstocks were not correlated with their respective T_{50}. We documented the same lack of correlation in data from two other plots over two years (data not shown), and therefore, moisture content of peach shoots is not predictive of their relative cold hardiness, but it is only useful in understanding the process of acclimation and deacclimation.

Flooding Effects on Non-flooded Trees

Wilting occurred on recently emerged leaves of flooded trees within 2-3 days after imposition of flooding. Symptoms often disappeared overnight and recurred whenever conditions likely to promote high vapor pressure deficits prevailed. New leaves on flooded trees were typically smaller and cupped with a dull finish compared to nonflooded controls. At end of 10 day recovery period, visible chlorosis was evident in basal leaves of flooded trees, although very little leaf abscission had occurred by that time.

Flooded trees of Montmorency on MxM 2, MxM 39 and Giessen clone (GC) 195/2 and 196/4 produced significantly less total new stem and leaf dw when compared to their respective controls. Total, root and trunk dw was generally higher for control trees compared with their flooded counterparts, although differences were not significant for any of the rootstocks tested.

Table 5.
Differences in moisture content of 'Redhaven' peach shoots on 8 different rootstocks are not correlated with T_{50} at each single date. Values measured on basal sections of one-year-old shoots.

Rootstock	DATE					
	10/21/86		2/9/87		3/19/87	
	RWC	T_{50}	HWC	T_{50}	HWC	T_{50}
Redhaven	40.1	-13.5	--	-21.3	41.2	-21.9
Halford	36.7	-16.2	--	-25.3	36.3	-23.3
Nemaguard	41.1	-14.6	36.4	-24.4	41.0	-23.8
H7338001	39.3	-15.2	38.6	-24.0	--	-24.5
Boone Co.	40.9	-15.5	40.4	-24.9	--	-23.7
Tennessee Natural	37.6	-13.6	36.7	-25.9	38.3	-25.4
Siberian C	41.4	-17.1	42.0	-24.9	42.7	-23.7
GF 655-2	42.8	-18.2	40.2	-25.8	35.4	-25.0

Shoot extension of flooded treatments slowed markedly within a few days after imposition of flooding. At end of 5 day flooding treatment, shoot extension rates of most rootstocks had fallen significantly below that of their respective controls. Ten days later (after relief of flooding treatments), only those trees on MxM 2, GC 148/1, Mazzard and MxM 60 were growing at rates not significantly different from their respective controls.

Net CO_2 assimilation of flooded trees generally declined slowly over the first 2-3 days of flooding and then dropped rapidly on most rootstocks (Table 6). At end of 10 day recovery period, flooding had significantly reduced g_1 of Montmorency on all rootstocks except MxM 2, GC 148/1 and Montmorency; while A was significantly depressed on all rootstocks except MxM 2, Mahaleb and Colt.

Table 6.
Reduction of net CO_2 assimilation^z (A) in leaves of Montmorency on various rootstock during five days of flooding and 10 days after relief.

	Days after start of flooding						Mean control A^x
Rootstock	1	2	3	4	5	15	(micromol m^{-2} s^{-1} -sd)
Mahaleb	99	90	71	59*^{w}	28*	73	9.49 - 2.87
Mazzard	111	109	103	84	52*	56**	10.63 - 2.06
Montmorency	105	110	97	65	43**	31*	8.89 - 2.82
Colt	100	92	94	39**	20**	61	11.00 - 2.02
MxM 2	94	86	82*	49	48	71	9.80 - 2.99
MxM 39	84	76	75	57**	33**	18*	9.45 - 3.38
MxM 60	99	104	94	73	37**	32**	9.83 - 2.37
148/1	92	92	95	57*	51*	52*	8.56 - 3.27
148/9	103	95	110	48	24*	21*	8.88 - 3.24
195/1	97	83	89	42**	25**	19**	9.09 - 2.42
195/2	95	85	90	39*	21*	19*	11.06 - 2.87
196/4	94	79	93	46*	31**	12**	9.49 - 2.17

^{w}Significance of difference between control and flooded treatments within each rootstock indicated at 5% (*) and 1% (**) levels, otherwise nonsignificant, F test.

^{x}Mean of 36 measurements: 4 reps each on day 0, 1, 2, 2, 4, 5, 8, 11 and 15 of experiment.

^{y}Flooding imposed on evening of day 0, relieved on evening of day 5; experiment terminated on day 15.

^{z}Expressed here as % of mean control rate on each date.

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PEACH TREE SHORT LIFE AS RELATED TO TREE PHYSIOLOGY AND CULTURAL PRACTICES

R.R. Sharpe, C.C. Reilly, A.P. Nyczepir and W.R. Okie

ABSTRACT

Soil fumigation with methyl bromide on a peach tree short life (PTSL) site in Georgia decreased nematode population densities and tree loss due to PTSL. Soil fumigation interacted with both rootstock and time of pruning. December pruned trees on Nemaguard rootstock without fumigation resulted in the greatest tree loss due to PTSL. With pre-plant fumigation, either Lovell or Nemaguard rootstock could be used and time of pruning had less effect. Sampling trees prior to the development of PTSL showed that nutritional status, free amino acid content, reducing sugars, tannins and prunasin content were not involved in the predisposition of trees to PTSL.

Peach tree short life (PTSL) continues to limit peach production in the Southeast despite more than 30 years of research on the problem. PTSL is a complex interaction of factors which result in the death of the above ground portion of the tree in the spring. The ultimate cause of tree death is bacterial canker (*Pseudomonas syringae* Van Hall) and/or cold injury (5), but several factors predispose trees to PTSL. They include the ring nematode, *Criconemella xenoplax* (Cx) (4), the use of Nemaguard rootstock (8), fall pruning (3), and low soil pH (1).

The purpose of this study was to determine the interactions and relative importance of four factors associated with the predisposition of trees to PTSL and to obtain data on the chemical composition of trees prior to the development of PTSL. A major problem in PTSL research is that not all trees in an orchard are affected equally; therefore, much of the chemical data concerning PTSL have been obtained after trees have developed visual symptoms. It is impossible to determine whether the chemical differences seen in these type studies play a role in the predisposition of trees to PTSL or are due to the PTSL syndrome itself. By monitoring chemical composition of trees on an individual basis prior to the development of PTSL, we attempted to determine whether differences noted after PTSL development are related to the predisposition of trees.

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MATERIALS AND METHODS

A field study was started in December, 1984. Treatments were: (a) fumigated (Fum) with methyl bromide (561 kg/ha) or non-fumigated (NF), (b) Lovell (Lov) or Nemaguard (Nem) rootstock, (c) December (Dec) or March (Mar) pruning, and (d) limed (Lim) or not limed (NL). Treatments were arranged in a split-plot design with lime being the main plot and with a factorial arrangement of the remaining treatments as subplots. There were nine trees per plot with six replications for a total of 864 trees.

Twig samples were obtained in December and March of each year to determine nutrient concentrations of individual trees. An arch punch was used to take trunk samples from the south side of selected trees 20 to 30 cm above the soil line. Each sample formed a 1.3 cm dia cylinder containing the bark and ca. 5 mm of xylem. These samples were analyzed for prunasin, ninhydrin-positive material (free amino acids), reducing sugars, and tannins (7).

RESULTS AND DISCUSSION

Pre-plant fumigation reduced Cx and root-knot nematode (*Meloidogyne* sp.) population densities as compared to non-fumigated treatments (Table 1). Nematode population densities increased with time and in May 1988, mean Cx population densities were 475 and 1000 nematodes per 100 cm of soil in the fumigated and non-fumigated treatments, respectively.

Fumigation, March pruning, liming, and the use of Lovell rootstock have been shown to increase tree survival (decrease incidence of PTSL); while no-fumigation, December pruning, low soil pH, and the use of Nemaguard rootstock have been associated with the development of PTSL (1,3,5,7). The pattern of tree death in this test followed the same trends as reported previously (Fig. 1) (8). Results indicate that fumigation had the greatest influence on tree survival. Only two of the fumigated trees (0.5%) died by 1988, whereas 24% of the non-fumigated trees died. Rootstock and time of pruning seem to have a similar impact on tree survival, with 18% of the December pruned trees and 19% of trees on Nemaguard rootstock died due to PTSL by 1988. Liming was the only factor which did not influence tree survival. The lack of results due to liming may have been due to the relatively high pH in the unlimed treatments. From May 1985 to May 1988, soil pH of the top 15 cm was reduced from 6.7 to 6.2 in the limed and from 5.9 to 5.6 for the unlimed treatments, respectively. Cummings (1) reported that liming can increase tree longevity if soil pH is below 5.6, but at higher pH ranges liming resulted in only small differences in tree survival.

Most reports concerning the predisposition of trees to PTSL have dealt with one or two factors at a time. One of the goals of this test was to investigate the interrelationships among several predisposing factors. In the fumigated treatments, time of pruning and rootstock were less important and only December pruned trees on Nemaguard

Table 1.
Effect of fumigation on population densities (number of nematodes per 100 cm^3 soil) of Criconemella xenoplax (Cx) and Meloidogyne sp. (RK) over time on peach.

	Fumigated[1]				Non-fumigated			
	Nemaguard		Lovell		Nemaguard		Lovell	
	Cx	RK	Cx	RK	Cx	RK	Cx	RK
Mar. 1986	0	0	4	25	324	0	215	175
Dec. 1986	264	1	38	30	1822	6	297	29
Dec. 1987	263	8	203	37	1412	12	544	108
May 1988	606	0	345	131	1272	0	728	161

[1] Applied as methyl bromide (98% methyl bromide plus 2% chloropicrin at 561 kg/ha).

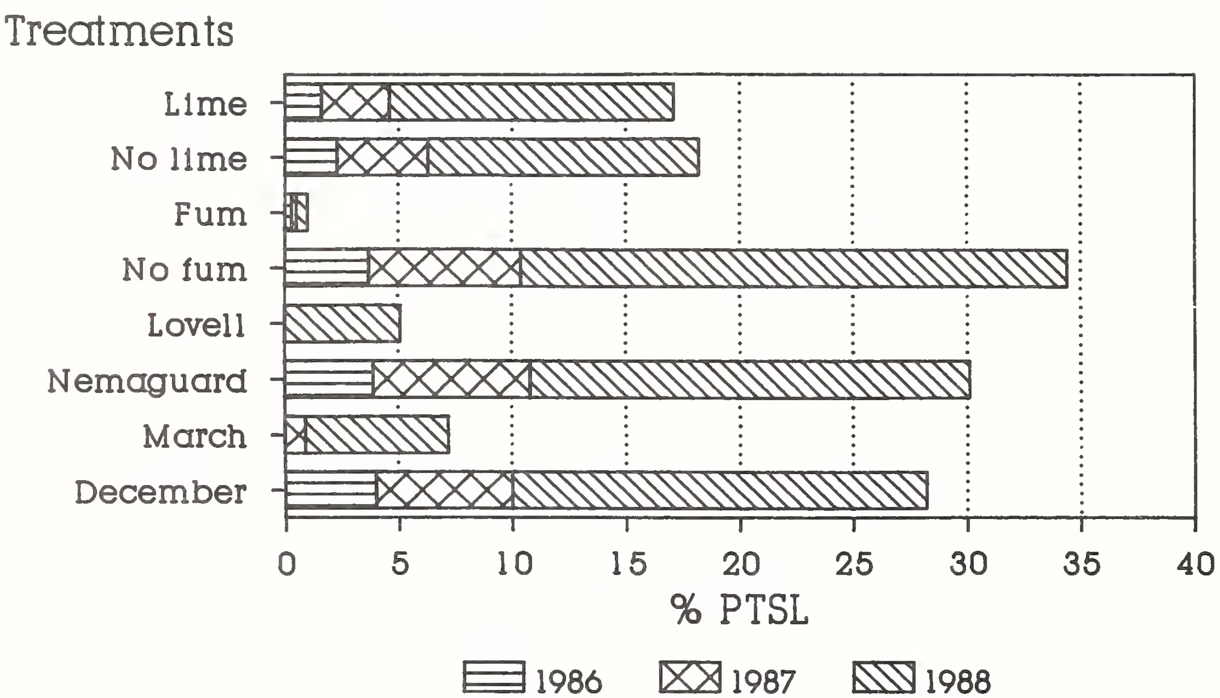

Figure 1. Effect of fumigation, rootstock, lime and time of pruning on incidence of PTSL.

rootstock developed PTSL (Fig. 2). Fumigation, however, is seldom practiced in the Southeast and without fumigation both rootstock and time of pruning become critical because the detrimental effects of the treatments are additive. March pruning of trees on Lovell rootstock (both recommended practices) in non-fumigated soil resulted in 3% PTSL. Changing the time of pruning from March to December (NF-Lov-Mar vs NF-Lov-Dec) resulted in a 6-fold increase in PTSL. Changing the rootstock (NF-Lov-Mar vs NF-Nem-Mar) resulted in a 7-fold increase in PTSL. Using all three factors associated with PTSL development (NF-Nem-Dec) resulted in the death of 53% of the trees after three years (Fig. 2).

To determine the possible role of nutrition in PTSL, previous research (2,9) has compared nutrient concentrations in PTSL and "healthy" trees. Differences between PTSL and healthy trees have been detected, but there has always been the question of whether these differences were a factor in PTSL development or a result of the PTSL syndrome. To answer this question, twig samples

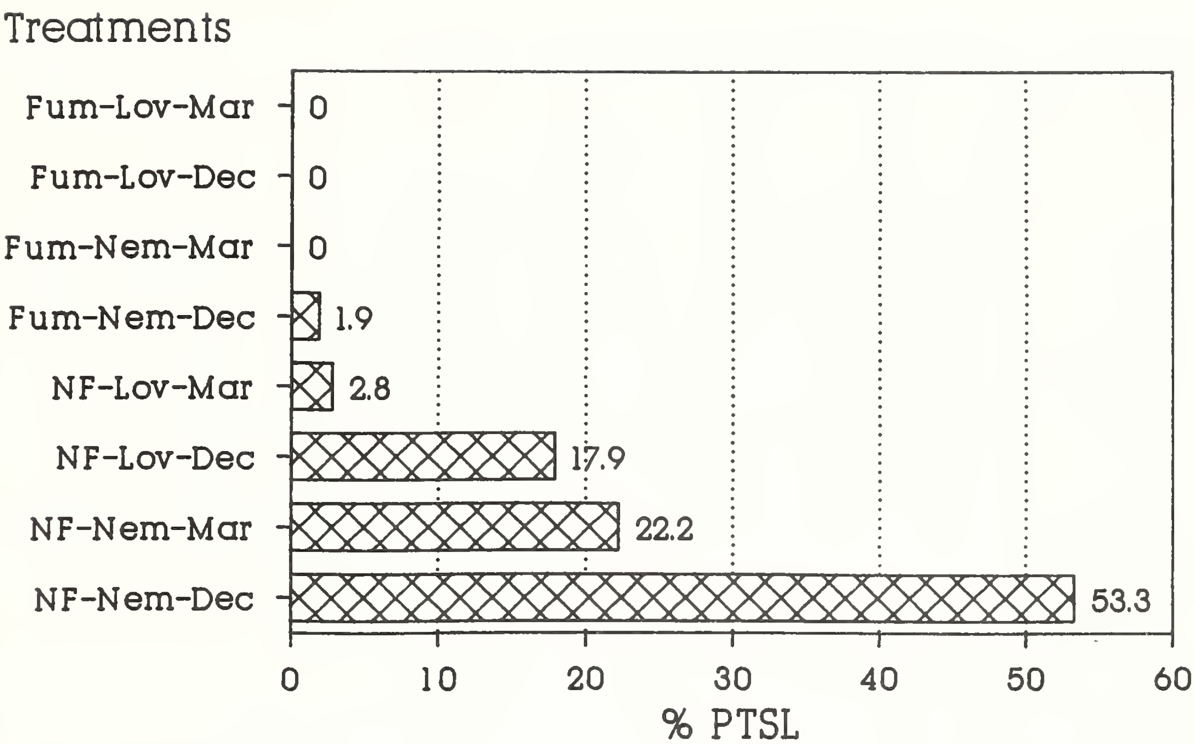

Figure 2. Interactions of fumigation, rootstock, and time of pruning on incidence of PTSL in 1988.

were obtained from each tree to determine if differences in nutrient concentrations occurred before PTSL symptoms were apparent. None of the nutrients we have analyzed to date seem to play a role in predisposition of trees to PTSL (Table 2). There were statistical differences in K and P concentrations between trees which died and apparently healthy trees, but the differences were minor and probably did not affect the health of the trees.

Concentrations of ninhydrin-positive material (free amino acids), reducing sugars, tannins, and prunasin were determined for selected trees in January, February, and March 1986. Differences in any of these chemical constituents prior to PTSL development would indicate the involvement of a major biochemical or enzymatic pathway in the predisposition of trees to PTSL. Research comparing healthy trees to trees exhibiting PTSL symptoms has shown that prunasin levels decreased by 90% and reducing sugars by 50% in PTSL trees (6). In this test, sugar and tannin concentrations in non-fumigated, fall pruned trees on Nemaguard rootstock were significantly greater in the January sampling than in the other treatments tested (Table 3). The importance of these differences is difficult to determine since they were apparent only in the January sampling, but the greater levels of reducing sugars may indicate that these trees were less dormant than trees in the other treatments. Four of the 36 trees sampled during 1986 developed PTSL. There were no differences in any of the chemical constituents when the four PTSL trees were compared to the 32 healthy trees (Table 4). The lack of significant differences in the data helps eliminate certain biochemical and enzymatic pathways as causal factors in the predisposition of trees to PTSL.

Table 2.
Comparison of nutrient status of trees prior to the development of PTSL and apparently healthy trees.

		Ca	K	P	Mg	Al	Mn	Zn	Fe
		%				ug/g			
Dec. 1985	Healthy	1.15	.61	.12	.17	29.1	28.0	20.5	28.7
	PTSL 1986	1.14	.57**	.14**	.16	25.9	28.4	19.9	25.4
Mar. 1986	Healthy	1.07	.54	.11	.17	37.4	30.1	18.7	31.3
	PTSL 1986	1.07	.62**	.12**	.17	33.7	33.9	19.3	30.9
Dec. 1986	Healthy	1.60	.51	.16	.19	21.8	40.9	38.3	37.8
	PTSL 1987	1.54	.54	.15**	.20	20.5	45.6	33.1	36.1
Mar. 1987	Healthy	1.59	.55	.15	.20	39.0	41.5	30.5	42.7
	PTSL 1987	1.62	.60**	.15	.21	38.5	44.1	26.2	42.2

**Significant at the 0.01 level of probability.

Table 3.
Effect of fumigation, rootstock, and time of pruning on ninhydrin-positive material, reducing sugars, tannins, and prunasin content in peach trees in 1986.

		Sampling Date			
		Jan. 13	Feb. 4	Feb. 17	Mar. 18
Fum-Lov-Mar	ninhydrin-	0.10	0.10	0.12	0.15
Fum-Nem-Mar	positive	0.10	0.10	0.11	0.15
NF-Nem-Dec	(mg/plug)	0.10	0.09	0.11	0.16
Fum-Lov-Mar	reducing	8.30B[z]	4.93	8.46	6.59
Fum-Nem-Mar	sugars	8.43B	4.72	8.14	6.33
NF-Nem-Dec	(mg/g)	10.16A	5.15	7.78	6.29
Fum-Lov-Mar	tannins	23.3B[z]	27.3	23.5	21.2
Fum-Nem-Mar	(mg/plug)	23.5B	28.7	24.9	20.6
NF-Nem-Dec		27.3A	28.2	22.7	18.7
Fum-Lov-Mar	prunasin	5.58	5.21	5.59	5.17
Fum-Nem-Mar	(mg/g)	4.83	5.00	5.17	4.90
NF-Nem-Dec		5.15	5.17	4.92	5.10

[z]Means followed by the same letter are not significantly different at the 0.01 level of probability.

Table 4.
Comparison of concentrations of ninhydrin-positive material, reducing sugars, tannins and prunasin in healthy and PTSL trees prior to the development of symptoms.

		Jan. 13	Feb. 4	Feb. 17	Mar. 18
Healthy	ninhydrin	0.10±0.01	0.10±0.01	0.11±0.01	0.16±0.02
PTSL	(mg/plug)	0.09±0.01	0.08±0.01	0.11±0.02	0.16±0.02
Healthy	sugars	8.68±1.30	4.80±0.63	8.14±1.43	6.36±0.85
PTSL	(mg/g)	11.24±1.09	5.98±0.59	8.03±1.37	6.72±0.37
Healthy	tannins	24.13±4.51	27.84±4.26	23.68±7.02	20.16±3.87
PTSL	(mg/plug)	29.17±2.69	30.00±3.38	23.5 ±4.59	20.50±1.45
Healthy	prunasin	5.19±1.17	5.13±0.94	5.26±1.01	4.96±0.69
PTSL	(mg/g)	5.16±0.68	5.06±0.76	4.94±0.40	5.82±0.56

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Breeding and Resistance Programs

ROOTSTOCK RELATIONSHIPS TO BACTERIAL CANKER, CROWN ROT, AND REPLANT PROBLEMS

Maxwell Norton

INTRODUCTION

In California, it is commonly presumed and in other parts of the United States there is experimental evidence indicating that Lovell peach rootstock is less susceptible to bacterial canker (BC) than Nemaguard. Three replicated rootstock trials were established and are being observed for several years to verify if the above is true under Merced County conditions.

The major fruit-growing areas of Merced County are commonly characterized by very coarse textures and varying pH, depending upon past soil and irrigation management practices. In preparation for examining rootstock effects, I surveyed 13 known BC sites and analyzed composite soil samples from "good" vs. poor areas for pH, EC, and percent sand. There was no statistically significant difference.

	pH	% Sand	EC
Good areas	5.7	76.5	0.72
Poor areas	5.5	77.9	0.81

Many more soil-related factors influence the incidence of BC than the above. Nematode samples showed large numbers of ring nematode in the BC areas compared to lesser numbers in the strong areas.

"Delhi" Plot

Starn cling peaches were planted out in ten replications of five trees each on Lovell and Nemaguard rootstocks. The entire ranch, which is classified as Delhi sand series, has a long history of BC. The plot was laid out in a fully randomized design. The field was fumigated with 1 lb. methyl bromide/tree hole.

By the spring of the fourth leaf, several trees had been killed by BC and several others were stunted and/or chlorotic. Trees have continued to become chlorotic and die.

Fourth Leaf	Lovell	Nemaguard
Missing or Replaced-Total	10	2
$\bar{X}$ #/rep	1.0 a	0.2 a
Stunted or Chlorotic-Total	9	18
$\bar{X}$ #/rep	0.9 b	1.8 a

Fifth Leaf	Lovell	Nemaguard
Missing or Replaced-Total	8	10
$\bar{X}$ #/rep	0.8 a	1.0 a
Stunted or Chlorotic-Total	6	9
$\bar{X}$ #/rep	0.6 a	0.9 a

Sixth Leaf	Lovell	Nemaguard
Missing or Replaced-Total	12	15
$\bar{X}$ #/rep	1.2 a	1.5 b

In many cases, trees would be stunted and/or chlorotic for two or more years before showing symptoms of BC and abruptly dying. Occasionally healthy and vigorous trees would lose a branch or limb due to BC that was subsequently pruned out by the grower.

"Livingston" Plot

In this plot, Lovell, Nemaguard, and Nemared were compared using 10 reps of 10 trees each in a 14' x 18' offset spacing under drip irrigation with Carson as the variety. The soil texture was sand, non-fumigated, with a history of BC. We used a randomized complete block design.

As has been observed in many blocks that have been converted to drip microsprinkler or microjet irrigation, there have been negligible amounts of BC. What has been most interesting about this plot has been the relative nematode (or lack of nematode) counts.

$\bar{X}$ Nematode Counts Per Replication

	Lovell	Nemared	Nemaguard
Pin	499	510	823
Stubby Root	90	30	30
Root Knot	18	0	0
Dagger	0	1.4	0.5
Ring	0	2.9	0
Lesion	0	0.6	0

This was unusual considering that the block was not preplant fumigated. It probably reflects the grower practice of growing rye grass before replanting, which underscores the importance of this practice in managing nematode populations. The presence of high numbers of pin nematodes relative to the low ring counts has been observed elsewhere and is probably significant.

As a result of the drippers being positioned too close to the trees, 15 trees died of crown rot by the end of the third year. Although not statistically significant, it is interesting to note that 10 Lovell, 5 Nemaguard, and zero Nemared died. It is widely presumed that Lovell is more tolerant to wet conditions than Nemaguard. Below is a summary of observations made in June of the sixth leaf after the problem with the drippers had been corrected.

University of California Farm Advisor, Merced County, 2145 West Wardrobe Avenue, Merced, CA 95340.

	Total Number of Trees in Plot			
	Stunted	Crown Rot	Replants*	BC Strikes
Lovell	16	3	0	4
Nemaguard	2	0	0	1
Nemared	25	2	10	2

*Replant is the only data that was statistically significant.

"Atwater" Plot

In this orchard, 100+ first-leaf Fay Elberta peaches on Nemaguard scattered through a 20-acre block had died due to BC. After backhoeing and fumigating with 1 lb. of methyl bromide, 50 single-tree reps of Lovell and Nemaguard replants were planted. After three years, we rated the trees for survivability and tree condition. The soil was Delhi sand and furrow irrigated. The original planting followed grapes.

	Total Number of Trees in Plot that Were:	
	Dead or Replaced	Stunted &/or Chlorotic
Lovell	9 a	14 a
Nemaguard	11 a	10 b

Examples of nematode data: (non-replicated)

	Ring	Lesion	Pin
Lovell	318	73	560
Nemaguard	1,051	22	36

DISCUSSION

While avoiding Nemaguard or Nemared rootstocks may be an important element in managing the peach replant syndrome in some parts of the United States, this does not seem to be a solution in sandy soils in Merced County. While ring nematode probably plays a significant role in the incidence of BC, simple relative resistance to ring does not seem to solve the problem.

While preplant fumigation, rotating with grain crops, post-plant application of nematicides and pH management all may be beneficial, they have yet to provide satisfactory control. Field observations suggest that the most significant reductions in BC and replant problems have resulted from converting to low-volume irrigation systems.

THE USDA/ARS STONE FRUIT ROOTSTOCK BREEDING PROGRAM, FRESNO, CALIFORNIA

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The stone fruit rootstock breeding program at the USDA/ARS Horticultural Crops Research Laboratory, Fresno, California emphasized the development of vigorous rootstocks that are resistant to both Meloidogyne incognita and M. javanica rootknot nematodes until 1980. As a result of this work Nemaguard, a peach rootstock, was released in 1959 and Nemared, a redleaf F_3 peach seedling of Nemaguard, was released in 1980. Both cultivars provide vigorous rootstocks resistant to the above nematodes.

The need for a range of vigor in rootstocks to satisfy the need for vigorous trees in replant situations and smaller trees to control excess vigor in very fertile soils became more apparent during this time. Interspecific hybrids have been shown to be a useful source for rootstocks varying in vigor from work done by researchers in France (7). Since interspecific hybrids do not breed true from seed or in many cases produce only a few seeds, the ability to be propagated from cuttings is a necessity for commercial production. Stone fruit cultivars were tested for their ability to root from dormant hardwood cuttings to determine their usefulness as parents in hybridization. Of the 41 peach and nectarine cultivars tested, Nemaguard and Nemared rooted at 69% and 51% in 1978 respectively, which was among the best for the peaches tested. Since they already have rootknot nematode resistance they were chosen as parents in a hybridization program. Almond X peach (Nemared) hybrids were made to develop vigorous rootstocks for poor soils and replant situations. Approximately 85 seedlings resistant to rootknot nematodes in greenhouse tests were selected and tested for rooting ability from dormant hardwood cuttings. Of these, 47 had over 70% rooting. Titan and 15-37, the two late blooming almonds used as parents had 0% rooting in 1978, while many of the F_1 hybrids rooted as well as or better than Nemared. These F_1 hybrids have not been released for trial because of the reduced need for vigorous rootstocks since Kester(2) released Hansen 2168 and Hansen 536 almond X peach rootstocks which provide vigorous rootknot nematode resistant rootstocks for the industry.

The last 10 years have seen a change from the normal wide spacing of 20' x 20' to closer "high density" plantings for apricots, peaches, nectarines, and plums for the fresh market. The reason for this has been to achieve earlier production and quicker returns on grower investment. For the closer plantings to be feasible, the vigor of the trees needs to be controlled. Several ways to do this are by pruning, growth regulators, genetic dwarf trees or by dwarfing rootstocks. We felt the ultimate resolution of the problem is with the use of dwarfing rootstocks although it is a very long term and difficult project. The commercial cultivars of P. besseyi and P. tomentosa used for dwarfing rootstock show incompatibility to most of the peach and nectarine cultivars and are only used for backyard trees. However, since they provide dwarfing it is logical to hybridize them with plum and peach to improve compatibility while retaining dwarfing and nematode resistance. Since a number of P. besseyi hybrids already exist, they were collected and tested for rooting from hardwood cuttings and for resistance to rootknot nematodes. Since then plum X peach, plum X almond hybrids and selections from other breeding programs have also been tested. Of the 145 cultivars, species and hybrids evaluated for rooting and rootknot nematode resistance, 15 have shown over 70% rooting and no galling. The genotypes having greater than 70% rooting and no galling are shown in Table 1.

A number of cultivars and selections that have no galling and reasonable rooting have been planted in preliminary trials to determine compatibility, dwarfing, and yield. To do this, dormant cuttings were made for propagation in a commercial nursery where rooting was essential for production of a grafted plant. Since the advent of in vitro tissue culture propagation methods, the requirement for propagation by hardwood cuttings can be relaxed and genotypes with low rooting need to be tested as well. The percent cuttings rooted, budded and percent growing is recorded in Table 2. Those showing reliable rooting with large enough growth after spring budding to be planted in the field trial were: P160G, St. Julian 53-7, P. besseyi 'Sioux,' Myran, Nemared, S3400, Sapalta, Myrobalan 29C, M2624, K146-40 and K41-10. Preliminary data shows a range of compatibility and vigor exists. Friar plum appears compatible with all these rootstocks but Springcrest peach has shown incompatibility with P. besseyi 'Sioux," Myrobalan 29C, M2624, K41-10 (all plums) and K146-40 (plum x peach). After the first crop, P160G, Sapa and Sapalta caused dwarfing of Friar (as indicated by trunk circumference) and yields greater than on Nemared. All of the rootstocks that dwarfed Springcrest yielded less than Nemared and in most cases showed incompatibility by tree death or yellowing of leaves with stunted growth. Additional rootstocks are currently being tested in a cooperative project by Ted DeJong and Scott Johnson. This trial will also look at yield, size and maturity of fruit as effected by rootstock in addition to dwarfing and compatibility.

With the anticipated loss of preplant and postplant chemical fumigation treatments for nematode control, rootstock resistant to other nematodes are also necessary. McKenry and Kretsch (5) have shown the distribution of root lesion nematode (Pratylenchus vulnus) and ring nematode (Criconemella xenoplax) is wide spread in California and can now be considered the most important nematodes since rootknot nematode resistance has been developed. A program to determine resistance to lesion nematodes was

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started in 1985 and resulted in the development of a greenhouse screening method (1). In this test Culver, et al. (1) established that nematodes per gram of root was a reliable indication of relative resistance to initial invasion and establishment after 120 days after innoculation. As a result of the screening done, P. japonica (IR-2 clone) and P. tomentosa 'Orient' have been identified to be more tolerant to lesion nematodes than Nemaguard, while P70-107 (almond x peach) and Citation have shown possible tolerance. Myrobalan 29C has been used as a tolerant standard based on lathhouse trials by Lownsbery and Serr (3) and on field trials by McKenry (4) where Friar plum yields after 4 and 6 years production were reduced 1.5% and 10% compared to 23% and 16% on Nemaguard. Myrobalan 29C in greenhouse trials appears similar in tolerance compared to P70-107 and Citation but less resistant than P. japonica and P. tomentosa 'Orient' (Table 3). S3400 also showed relative low levels of lesion nematode penetration but has been very susceptible to wet soil in the greenhouse. A field trial to determine relative resistance and correlation with greenhouse results of P. tomentosa 'Orient,' P. japonica, Myrobalan 29C and Nemaguard is needed.

Currently the ring nematode screening procedures developed by Okie et al. (7) are being tested and adapted to our conditions in California.

Table 1.
Prunus selections that had greater than 70% rooting and no rootknot nematode galling.

Name	Type	Name	Type
9-21	peach	Sapa	P. besseyi x Sultan
9-24	peach	Sapalta	Sapa O.P.
P118-1	peach	S3400	P. besseyi x peach
Okinawa	peach	P160G	Plum x Peach
P. pumila 'Mondo'	sand cherry	Myran	Myro P322 x peach S1058
P. besseyi 'Sioux'	sand cherry		
P. cistena	P. besseyi x purple leaf P. cerasifera	PI1869	Damas
		GF 655-2	St. Julian
Oka	P. besseyi O.P.	K41-10	purple leaf P. cerasifera

Table 2.
Rooting of rootstocks in commercial nursery in 1983 and 1984.

	1983			1984	
Name	% Rooting	% Budded	Brownrot	% Budded	% Growing
Opata	100	0	*	0	-
P160G	95	94		87	96
Sapa	80	25	*	20	33
S3400	80	0	*	73	67
St. Julian 53-7	70	79	*	83	92
P. besseyi 'Sioux'	62	100	*		
P. cistena	50	33			
Myran	55	82		50	40
Nemared	50	100		90	85
Oka	33	0	*	0	-
P. tomentosa 'Orient'	35	43	*		
Citation	25	60		33	70
Sapalta	30	100	*	0	
K146-35	20	33			
P. japonica	16	67	*		
P. pumila 'Mondo'	10	50	*	43	0
Myro 29C				100	100
K41-10				97	100
M2624				90	87
Lantz				57	41
K146-40				47	71
St. Julian A				47	0
K144-100				17	100

*Blossom blight in many cases caused death of the cutting.

Table 3.
Results of rootstocks treated with 150 verniform lesion nematode larvae/plant 290 and 415 days after treatment (DAT).

		290 DAT	415 DAT		
Name	Treatment	Nema/gm root	Nema/gm root	Top wt. (gm)	Root wt. (gm)
P. tomentosa	control*			10.1	10.6
	w/lesion	1.9	0.3	15.1	26.6
P70-107	control			90.1	
	w/lesion	157.8	243.4	63.9	
Myro 29C	control			166.4	107.3
	w/lesion	85.0	345.4	79.6	98.5
Citation	control			97.7	56.5
	w/lesion	168.8	149.3	42.5	52.1
Nemaguard	control			92.9	83.7
	w/lesion	379.7	151.8	39.7	83.5
P. japonica	w/lesion	4.5	3.1		

*P. tomentosa control was over watered.

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